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Atlantis Model Development for the Northern Gulf of California

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Atlantis Model Development for the Northern Gulf of California

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Executive Summary

Atlantis ecosystem models are developed for the marine ecosystem of the northern Gulf of California, Mexico, in order to provide new tools for investigation of ecosystem-based fisheries management (EBFM) questions and ecological hypotheses. The models are based partly on original fieldwork conducted for this project by the Northwest Fisheries Science Center and by the PANGAS (Pesca Artesanal del Norte del Golfo de California–Ambiente y Societad [Small-scale Fisheries in the Northern Gulf of California–Environment and Society]) project (http://pangas.arizona.edu/), a consortium of academic and nongovernmental institutions in Mexico and the United States.

In this report, we detail construction of two Atlantis models, one representing the northern gulf in the year 2008 and another representing it in 1985. The 2008 model was based on the best current data and utilized new biomass estimates from scuba transects and trawl sampling, estimates of fisheries catch from port-level surveys, log books and community interviews, as well as other published and unpublished data. Polygon geometry was designed to represent ecologically important gradients and boundaries, reflect stock assessment and catch data organization, and demark existing and proposed spatial management areas.

The spatial distribution of species biomasses in Atlantis was estimated using a habitat-based algorithm with parameters optimized to recreate observed transect data. We briefly described the diet matrix initialization procedure for the Atlantis model. This process relies on a statistical analysis of stomach contents collected for this project and diet composition values from the literature. Time series of relative abundance were developed based on local environmental knowledge interviews conducted for this project, simple population models, and other information sources; these data sets were amalgamated using a fuzzy logic methodology. Other aspects of gulf ecology were integrated into the model, such as nutrient distribution, water movement, animal migration and behavior, animal production and consumption rates, and age distributions.

A 1985 model was developed from the 2008 model by analyzing changes in gulf ecology over the intervening 23 years. We drove the 1985 model forward 23 years using historical catch trends assembled here and oceanography patterns from a regional ocean modeling system. The dynamic simulation from 1985 to 2008 achieved a satisfactory fit to time series information, while the simulation end state bore a close resemblance to the modeled 2008 ecosystem. The dynamic behavior of the 2008 model was improved by transferring the dynamic (fitted) parameters of the 1985 model and assuming stationarity in some ecosystem qualities. The 2008 model, suitable for forward-looking simulations involving EBFM questions, was validated here through a series of diagnostic simulations including analysis of catch and biomass equilibriums under a range of fishing pressures. The unexploited biomasses of functional groups were evaluated and they corresponded well to estimates made by previous authors. This document

can serve as a reference for future work investigating EBFM questions and ecological hypotheses using the northern Gulf of California Atlantis models.

Acknowledgments

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Abbreviations and Acronyms

AVHRR	advanced very high resolution radiometer
BCS	Baja California Sur
CEDO	Centro Intercultural de Estudios de Desiertos y Oceanos
CIBNOR	Centro de Investigaciones Biologicas del Noroeste
CICESE	Centro de Investigacion Cientifica y de Educacion Superior de Ensenada
CICIMAR	Centro Interdisciplinario de Ciencias Marinas (Interdisciplinary Center for Marine Sciences) of the National Polytechnic Institute
COADS	Comprehensive Ocean-Atmosphere Data Set
COBI	Comunidad y Biodiversidad
CONSPESCA	Comision Nacional de Acuacultura y Pesca
CPUE	catch per unit effort
CRIP	Centro Regional de Investigacion Pesquera
CSIRO	Commonwealth Scientific and Industrial Research Organization (Australia)
EBFM	ecosystem-based fisheries management
EwE	Ecopath with Ecosim
fichas	fisheries information brochures
FL	fork length
ICLARM	International Center for Living Aquatic Resources Management, now known as WorldFish Center
IGBEM	Integrated Generic Bay Ecosystem Model
INAPESCA	Instituto Nacional de Pesca
ISPM	Isla San Pedro Martir
LEK	local environmental knowledge
MLE	maximum likelihood estimate
MSY	maximum sustained yield
mt	metric tons
NARR	North American Regional Reanalysis
NH	ammonia
NMFS	National Marine Fisheries Service
NO	nitrate
NWFSC	Northwest Fisheries Science Center
PANGAS	Pesca Artesanal del Norte del Golfo de California–Ambiente y Societad (Small-scale Fisheries in the Northern Gulf of California–Environment and Society)
PDO	Pacific decadal oscillation
ROMS	regional ocean modeling system
SAGARPA	Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion (Secretary of Agriculture, Ranching, Rural Development, Fisheries, and Food Supply)
SCRUM	S-coordinate Rutgers University Model

SEMARNAT	Secretaria de Medio Ambiente y Recursos Naturales (Secretary of Environment and Natural Resources)
SODA	simple ocean data assimilation
TL	total length
UA	University of Arizona
UCLA	University of California Los Angeles
UCSC	University of California Santa Cruz
UCSD	University of California San Diego
UW	University of Washington

Introduction

Ecosystem-based Fisheries Management

Over the last 20 years, fishery managers, scientists, and other stakeholders have come to acknowledge the need to expand the scope of fishery management techniques beyond the traditional single-species approaches that have so far played a central role in the regulation of world fisheries. There has been a dramatic increase in the variety of ecosystem modeling approaches under development and number of systems being studied (Christensen and Walters 2005). The field is moving forward in response to calls for increased use of ecosystem-based fisheries management (EBFM) approaches (FAO 2003, NOAA 2003, Pitkitch et al. 2004, U.S. Commission on Ocean Policy 2004, European Commission 2008), which can supplement single-species methods.

The past few decades have seen serious and well-documented declines in the health of some exploited marine stocks (Pauly et al. 1998, Jackson et al. 2001, Myers and Worm 2003). The exclusive use of single-species methods has been implicated in certain failures (Walters et al. 2005), although reasons for stock collapses are complex and varied (Mace 2004). Nevertheless, EBFM seems a useful approach when we consider not only the unprecedented level of pressure put on the marine environment by growing human populations, but the emergence of many new marine industries that compete for space and resources, add contaminants to the environment, or otherwise affect marine fisheries. These include aquaculture, ecotourism, oil and gas exploration and development, technological developments in renewable energy, and agriculture. Modern fisheries management requires tools that can discern the impacts of these industries, describe interactions between fishing sectors, evaluate the compounding effects of marine use policies, and weigh the costs and benefits of policy decisions across economic, social, and ecological axes. Ecosystem models can help fill this role. They also provide the opportunity to gauge less tangible benefits of marine conservation. Through use of these models, ecosystem services may be described and factored into policy decisions (Ainsworth et al. 2008b). Ecosystem models will continue to be become more useful in the future as the variety of stressors increases and more attention is paid to the impact of climate.

In the Gulf of California, at least 30,000 commercial and artisanal fishers rely directly on the marine environment (Guerrero-Ruíz et al. 2006), while processing and other sectors benefit indirectly from fisheries. Although fishing remains the most important economic activity in the Gulf of California (Lluch-Cota et al. 2007), the economy of the area continues to diversify. More than 900 aquaculture operations now operate on the east coast, most established in the last 15 years (Lluch-Cota et al. 2007), and numerous hotels and condominiums are being constructed, many to support the lucrative recreational fishing sector. Ecotourism is also popular in the area due to the unique biology and diversity of organisms (Guerrero-Ruíz et al. 2006, Cárdenas-Torres et al. 2007). Management of northern gulf resources may benefit from a unified EBFM approach (Sala et al. 2004) because of the emergence of these new industries, continued concerns regarding terrigenous pollution (Ortiz-Lozano et al. 2005, Orduña-Rojas and Longoria-Espinoza 2006), and the present decline of commercially valuable species (Lozano-Montes et al. 2008).

PANGAS

To further EBFM in the northern Gulf of California, a consortium of academic institutes and nongovernmental organizations in the United States and Mexico began an initiative in 2005 called PANGAS (http://pangas.arizona.edu/). PANGAS (Pesca Artesanal del Norte del Golfo de California–Ambiente y Sociedad [Small-scale Fisheries in the Northern Gulf of California–Environment and Society]) is aimed at supporting sustainable fisheries in the region by 1) characterizing small-scale fisheries in the area and studying the species on which they depend, 2) developing an integrative approach for research and management of resources, 3) soliciting stakeholder involvement in management, and 4) engaging in training and capacity building.

PANGAS is committed to developing species-specific management plans to improve sustainability of fisheries resources and regional EBFM plans that may be submitted to Mexican fisheries authorities, Comisión Nacional de Acuacultura y Pesca (CONAPESCA) and Instituto Nacional de Pesca (INAPESCA). Institutes involved with the PANGAS initiative are the University of Arizona (UA), Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), the University of California Santa Cruz (UCSC), Centro Intercultural de Estudios de Desiertos y Océanos (CEDO), Comunidad y Biodiversidad (COBI) and Pronotura Noroeste. The Northwest Fisheries Science Center (NWFSC) has offered support to PANGAS in terms of fieldwork, modeling, analysis of data sets, and training in Atlantis ecosystem modeling.

Atlantis Model

At NWFSC, we developed an Atlantis ecosystem model (Fulton 2001, Fulton et al. 2004b) of the northern Gulf of California that integrates original field data from sampling by the PANGAS project and others to serve as a long-term aid in developing management strategies for this region of Mexico. The model is intended as a tool for managers and researchers to test alternative EBFM policies; for example, those involving marine protected areas, gear restrictions, seasonal closures, and harvest rules aimed at conserving wildlife and achieving sustainable use of resources. The model is also capable of testing ecological hypotheses and simulating climatological scenarios.

Atlantis is a biogeochemical marine ecosystem model developed by scientists in Australia at the Commonwealth Scientific and Industrial Research Organization (CSIRO). The model summarizes biological players in an ecosystem through use of functional groups, which are groups of species aggregated by trophic, life history, or niche similarities. Atlantis integrates physical, chemical, ecological, and fisheries dynamics in a three-dimensional, spatially explicit domain. Numerous submodels simulate hydrographic processes, chemical and biological factors determining primary productivity, food web interactions between species, biogenic habitat dependence of groups, nutrient loading, and other chemical and biophysical features crucial to a functioning ecosystem. Atlantis is well suited to represent important ecological characteristics of the northern gulf such as the influence of exogenous nutrient and freshwater input entering the gulf from agriculture and coastal development in Sonora. It can also represent the strong latitudinal gradient of turbidity due to the Colorado River, the natural stratification of salinity and temperature present in the area, and the important functioning of biogenic habitats such as seagrass and rhodolith beds as fish rearing habitat and refuge space. The influence of management regimes, which affect the area of operation, dates of operation, or selectivity of fishing fleets in the fisheries submodel, can be analyzed throughout the food web.

Objective of this Technical Memorandum

This technical memorandum provides basic parameterization of an Atlantis model, which represents the present day ecosystem of the northern Gulf of California (ca 2008). It describes the spatial delineation of the ecosystem into polygons, the aggregation of species into functional groups, and data sources and data processing methods used for all biological and life history parameterization. This document also reports on the various supporting fieldwork exercises organized by NWFSC to provide data for the model. These include an inshore trawl survey using an underwater camera to estimate catchability, a fish morphometric study to obtain gape size and length-weight ratios, and a fish gut content survey to provide a diet matrix for Atlantis (described in Ainsworth et al. 2010). Using the present-day model as a template, we also constructed a 1985 model. Development of this historical model relies on estimates of past species biomass, which were generated using a mix of literature references and local environmental knowledge (LEK) collected for this project and interpreted using a fuzzy logic approach (described briefly here and published in detail in Ainsworth in press). The 1985 model is driven forward to the present day under historical fishing patterns and oceanography described by a regional ocean modeling system (ROMS). Having tuned the dynamic parameters of the 1985 model by fitting the simulation to historical data, those parameters are transferred to the 2008 model assuming stationarity in key model parameters. Management studies using Atlantis will be described in later publications.

Northern Gulf of California

The Gulf of California, also called the Sea of Cortez or the Sea of Cortés, is a semienclosed sea that separates the Mexican mainland from the Baja California Peninsula. It is an important fishery region in Mexico, in some years providing 40% of total catch by volume to Mexico, mainly from sardine and anchovy fisheries (Lluch-Cota et al. 2007). In the northern gulf (Figure 1), the marine ecosystem provides income and food security to as many as 3,800 artisanal fishers who operate small fishing vessels called pangas from 17 permanent fishing communities (Moreno-Baez et al. 2010). The area is important from an ecological view point for its high fish biodiversity and endemism (Gilligan 1980, Enriquez-Andrade et al. 2005), invertebrates (Brusca 2006, Hendrickx 2007), and plants (Felger 2000). It is a nesting place for sea birds (Velarde and Anderson 1994) and an important feeding and breeding ground for pinnipeds, cetaceans, and marine turtles (Lluch-Cota et al. 2007).

A range of threats troubles fisheries and ecology in the region. Overexploitation of living resources, which began decades ago with the pursuit of the endemic croaker totoaba (*Totoaba macdonaldi*), has resulted in critical depletions of commercially targeted fish (Sala et al. 2004, Lercari and Chávez 2007), while incidental captures threaten endangered species like the endemic porpoise vaquita (*Phocoena sinus*) (Jaramillo-Legorreta et al. 2007). Wide-scale

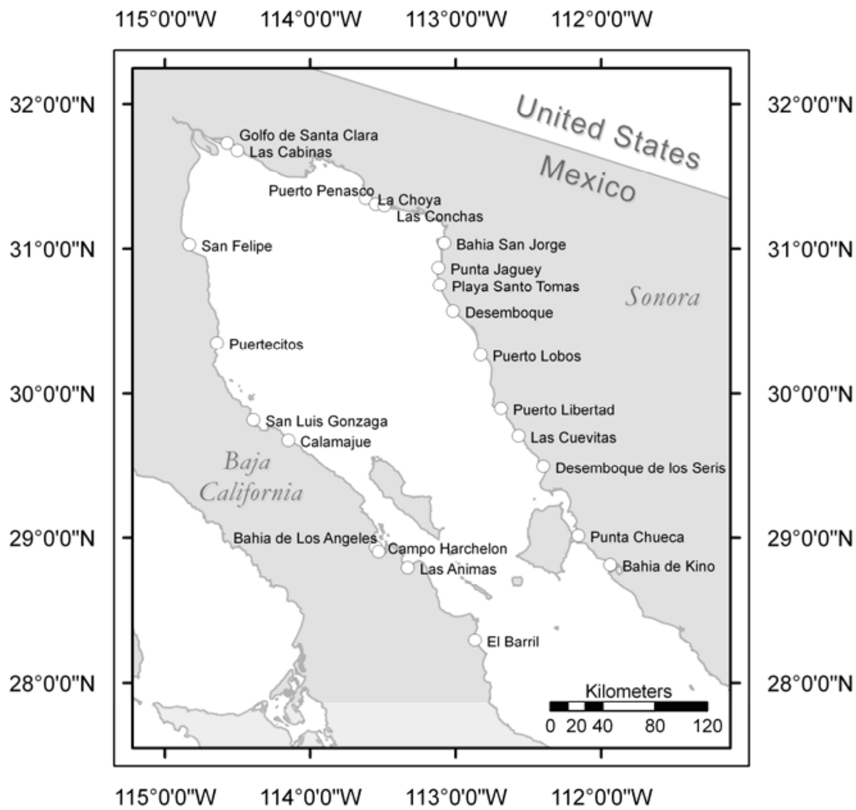

Figure 1. Northern Gulf of California, Mexico, with major fishing communities.

alteration of the habitat caused by regulation of the Colorado River and coastal development has impacted fisheries production (Galindo-Reyes et al. 1999, Galindo-Bect et al. 2000) and radically altered the marine assemblage (Rodríguez et al. 2001). More than 7 million people now live in the Sonoran Desert and the population continues to expand at a high rate (Brusca et al. 2001). Brusca et al. (2005) provide a useful summary of the history of biological study in the Gulf of California.

Physical Environment

Colorado River

The northern gulf is strongly influenced by the Colorado River, which supplies the northern delta area with freshwater, nutrients, and sediment. It begins in the Rocky Mountains and winds 2,800 km through Colorado, Utah, Arizona, Nevada, and California. The river supplies water to more than 30 million people and irrigates 1.5 million hectares of farmland in the United States and Mexico (Brusca et al. 2001). Many dams are located on the Colorado River, the largest ones being the Hoover Dam (Nevada-Arizona 1935) and the Glen Canyon Dam (Arizona 1963). Other flow regulating structures include the Shadow Mountain Dam (Colorado 1946), Granby Dam (Colorado 1950), Davis Dam (Arizona-Nevada 1951), Parker Dam (Arizona-California 1938), Headgate Rock Dam (Arizona 1941), Palo Verde Dam (California 1957), Imperial Dam (Arizona 1938), Laguna Diversion Dam (Arizona 1924) and the

Morelos Dam (Baja California 1950). Numerous tributaries feed into the Colorado River along its extent, and these are also highly regulated (Lavín and Sanchez 1999).

This system of dams has removed the seasonal modulation of freshwater input, while diversion of water for agricultural uses, some 18 billion $m^3 \cdot yr^{-1}$, has reduced freshwater flow to the Colorado River estuary to a minute fraction of the historical amount (Turner and Kapiscak 1980, Carbajal et al. 1997, Lavín and Sanchez 1999). A flooding period that began in 1983, concurrent with a major El Niño event, continued for 10 years and temporarily increased the amount of water reaching the northern gulf to 4.8 billion $m^3 \cdot yr^{-1}$ (Glenn et al. 1996). This is close to pre-Hoover Dam levels.

The Colorado River is managed under numerous agreements collectively referred to as the "Law of the River," which includes contracts and regulations between seven U.S. basin states and Mexico (Bureau of Reclamation 2008). There is recognition, however, that total legal entitlements to water (20.2 billion $m^3 \cdot yr^{-1}$) exceed the historical average flow (16 billion $m^3 \cdot yr^{-1}$) (Flessa 2004). Moreover, the human population in the U.S. southwest region continues to grow rapidly. Arizona and Nevada have been among the fastest growing states (U.S. Census Bureau 2005).

Reduced levels of freshwater flow have likely altered the species composition in the northern gulf by changing salinity patterns and reducing the amount of available estuarine habitat. For example, before the dams, the Colorado delta clam (*Mulinia coloradoensis*) dominated the invertebrate assemblage while only a fraction of the fauna consisted of the white clam (*Chione californiensis*); presently, that ratio has been reversed (Flessa et al. 2001). The loss of estuarine habitat and reduced nutrient inflows may have additional secondary affects. The life history of the endangered totoaba has apparently changed since the construction of the dams; individuals now grow slower and mature later, among other anomalies (Rowell et al. 2008). This reduces lifetime fecundity and may make the species more vulnerable to the effects of bycatch mortality. Invading species also present a challenge to the ecology of the northern Gulf. In the lower reaches of the Colorado River, 38 fish species out of an estimated 125 are believed to have been introduced by humans (Mueller and Marsh 2002).

Temperature

The northern Gulf of California experiences wide seasonal variations in sea surface temperature, from 10–33°C (Thomson et al. 2000). The semiannual and annual amplitudes of temperature change in the northern gulf are greater than the southern gulf by a factor of two (Soto-Mardones et al. 1999). A seasonally reversing sea surface temperature gradient is present, with high temperatures occurring in the northwest area of the northern gulf during summer and lower temperatures in the northwest during winter (Alvarez-Borrego and Galindo-Bect 1974). The northern region typically has lower temperatures than the central or southern portions of the Gulf of California due to intense tidal mixing (Soto-Mardones et al. 1999). From the 1970s to the 1990s, the average sea surface temperature in the gulf underwent a slow increase with increasing seasonal amplitude, but this trend has apparently ceased (Lluch-Cota 2004).

Salinity

Salinities, which ranged from 32–35‰ prior to dam construction, now range 35–45‰ (Flessa et al. 2001); saline coastal estuaries can range up to 40‰ (Brusca 2006). The region is currently an inverse-estuary due to minimal freshwater input and a high evaporation rate ($E \approx 1.1$ $m \cdot y^{-1}$) (Lavín et al. 1998). The system can, however, change abruptly to estuarine conditions during heavy rain El Niño events and rare snow melts (Lavín and Sanchez 1999). Current flow in the northern gulf is heavily influenced by evaporation in the mouth of the Colorado River. Dense saline water sinks and flows from the estuary along the seafloor into the Wagner Basin, a deep (200 m) region about 60 km east of San Felipe (Lavín et al. 1998). At the end of summer (August), after evaporation has occurred, salinity is at its highest. When the seawater cools, the gravity current intensifies reaching a maximum between December and March.

At its peak, the convection causes sporadic vertical temperature stratifications that have been observed during neap tides (Lavín et al. 1998, Lavín and Sanchez 1999), but the northern gulf is otherwise well mixed throughout the year (Argote et al. 1995, Lavín and Sanchez 1999). The gravity current emanating from the western pass of the Colorado River estuary (Baja California channel) enforces a cyclonic circulation system that draws less saline oceanic waters into the eastern pass (Carriquiry and Sanchez 1999). The flow and counterflow are driving influences on sediment suspension and transport at the river's mouth, and may also influence the drift of plankton, eggs, and larvae (Carriquiry and Sanchez 1999). There is little freshwater influx on the west coast of the gulf, but the east coast has numerous coastal lagoons and muddy bays that filter an appreciable amount of freshwater into the gulf (Thomson et al. 2000).

Sediment flux and circulation

The northern Gulf of California is very dynamic due to the strong influence of tidal currents, wind stress, upwelling, and solar heating. Sediment flow to the northern gulf was seriously reduced in the twentieth century because of dam construction. Before dams were in place, 16.7 million acre-feet of water entered the northern gulf annually from the Colorado River (Brusca et al. 2005), depositing 145 million metric tons (mt) of sediment each year on the delta (Van Andel 1964). However, large reservoirs now act as sediment traps. With this input removed, wind driven currents and tidal currents now erode the depositional basin. Suspended sediment particles from the western limb of the Colorado River are transported to the western margin of the gulf where much of the material settles in the Delfín and Tiburón basins south of the delta area (Carriquiry and Sanchez 1999).

Tidal motions increase the sediment deposition rate along the coast of Baja California. A high tidal amplitude in the northern gulf, up to 12 m difference between the high and low at spring tide (Lavín et al. 1998, Carriquiry and Sanchez 1999, Thomson et al. 2000) and a high tidal current speed ($1\ m \cdot s^{-1}$) (Alvarez-Sánchez et al. 1993, Lavín et al. 1998) keep sediments in suspension, resulting in turbid waters year round (Lluch-Cota et al. 2007). Optical properties in the northern gulf region are therefore dominated by the suspended particles, but further south in the gulf, ocean color and opacity are more strongly influenced by phytoplankton concentration (Barnard et al. 1999, Pegau et al. 1999).

Ocean climate in the Gulf of California, particularly sea level and temperature, is heavily influenced by Southern Oscillation and El Niño, while the transition between El Niño and anti–El Niño periods regulates which of the cooler California Current or the warmer Costa Rica Current is available at the mouth of the gulf for water exchange (Baumgartner and Christensen 1985, Cisneros-Mata et al. 1997). Biological patterns in the northern gulf have also been shown to relate to the Pacific Decadal Oscillation (PDO) index (Lercari and Chávez 2007). North of the Midriff Islands (Angel de la Guarda and Tiburón), a wind-driven, counterclockwise gyre is present in the summer and fall; the direction of rotation reverses in winter and spring (Beier 1997, Lavín et al. 1997).

Physical geography

The northern gulf study area contains mainly shallow shelf areas between 50 and 200 m in depth. There are only small depressions; the largest is the Wagner Basin southeast of Roca Consag. In contrast, south of the Midriff Islands the ocean floor has deep areas, with five basins including the Delfin (900 m), the Salsipuedes (1,400 m), San Esteban, Tiburón, and San Pedro Mártir basins, which reach depths similar to the Delphin Basin (Case et al. 2002). The Baja California coastline is predominately rocky from Bahia San Felipe to San Francisquito, with some interspersed sandy beaches. The Sonoran side is predominantly sandy beach with some rocky areas from Puerto Los Lobos to Punta Tepopa.[1]

Biology

Primary production

The Gulf of California has features that are conducive to high primary productivity, although little information is available regarding the variability in time and space of production (Santamaría-del-Angel et al. 1994). A distinctive feature of the northern gulf is persistent stratification of the upper water column that occurs in the summer, leading to nutrient depletion above the thermocline that limits phytoplankton growth (Thunell et al. 1996). In areas south of the Colorado River estuary, upwelling and terrigenous nutrient loading ensure that coastal waters remain green and productive, absorbing photosynthetically available radiation, while waters in the central gulf are typically clearer and more oceanic (Barnard et al. 1999).

Water sampling and remote sensing suggest that upwelling occurs on the east coast of the gulf (Santamaría-del-Angel et al. 1994, Gaxiola-Castro et al. 1999), although turbidity in coastal waters caused by suspended material and dissolved organic matter can bias ocean color data (Hu et al. 2000, Zhang et al. 2006). The northeastern portion of the Gulf of California may be subject to this bias due to a high concentration of suspended material from tidal mixing (Pegau et al. 1999). Most of the primary production available on the west coast is due to gyre transport of upwelled nutrients from the east (Santamaría-del-Angel et al. 1994).

[1] R. Loaiza-Villanueva, CEDO, Puerto Peñasco, Sonora, Mexico. Pers. commun., March 2008.

Species biodiversity

The Gulf of California is a biodiverse area containing at least 908 marine fish species (Hastings and Findley 2007), 4,852 invertebrates, and 222 nonfish vertebrates (Brusca 2006). In the northern gulf are 576 marine fish species, as estimated in this report (see Methods Section, Fish Group Composition subsection), about 177 nonfish vertebrates (Brusca et al. 2005), and 2,300 invertebrate species (Brusca et al. 2001, Lluch-Cota et al. 2007). Most invertebrate species occur in the littoral fringe from the intertidal zone to the 20 m isobath (Lluch-Cota et al. 2007).

There is a gradient of increasing biodiversity from north to south in the Gulf of California so that at the extreme north end, in the Upper Gulf and Colorado River Delta Biosphere Reserve, there are only 1,050 species of macroinvertebrates (Lluch-Cota et al. 2007) and 260 species of marine fish (Hastings and Findley 2007). One factor to account for reduced biodiversity in the northern gulf is winter temperature, which can drop low enough to prohibit tropical species (Hastings and Findley 2007). Nevertheless, there is a notable diversity of cartilaginous fishes (Chondrichthys) recorded in the northern gulf, with as many as 58 species of sharks, rays, and chimeras (Brusca et al. 2005, Hastings and Findley 2007). There is a high incidence of endemism in the northern Gulf of California for fishes (Gilligan 1980) and invertebrates (Brusca 2006, Hendrickx 2007).

Conservation

The area around the mouth of the Colorado River was recognized as a fishing refuge in 1955 and eventually declared a national reserve in 1974, although no concrete protection actions followed these designations (Cudney-Bueno and Turk-Boyer 1998). The Upper Gulf of California and Colorado River Delta Biosphere Reserve (Reserva de la Bisfera del Alto Golfo de California y Delta del Río Colorado) was designated in 1993, among other reasons, to conserve the endemic croaker totoaba and the endemic vaquita, as well as species such as the desert pupfish (*Cyprinodon maculariu*), Yuma clapper rail (*Rallus longirostris yumanensis*), and Delta silverside (*Colpichthys hubbsi*) (Diario Oficial de la Federación 1993, Vidal 1993, SEMARNAT 1995). The biosphere reserve encompasses about 4,700 km^2 of sea space and extends from San Felipe in Baja California Norte (Punta Machorro) to just north of Puerto Peñasco in Sonora. The reserve consists of a large buffer zone and a core or nuclear zone that extends from El Estero La Ramada north of San Felipe to El Golfo de Santa Clara in Sonora. No fishing is allowed in the nuclear zone, except for traditional practices of the aboriginal Cocopá people and clam harvesting by locals (SEMARNAT 2003). Fishing is restricted in the buffer zone.

Other marine reserves in the northern gulf include the Bahia de los Angeles y Canales de Ballenas y Salsipuedes, declared in March 2007 (Diario Oficial de la Federación 2007). This extensive reserve encloses Bahía de los Angeles (in Baja California), Isla Angel de la Guarda, and the Canal de Ballenas, a baleen whale migration corridor and rare area in which whale sharks (*Rhincodon typus*) consistently aggregate (Cárdenas-Torres et al. 2007). The reserve encompasses nearly 3,000 km^2 of sea space and contains six small nuclear zones, none larger than 100 hectares, between Bahía de los Angeles and El Barrill: Campo Polilla, estero las Cahuamas (east and west coast), estero la Mona, Ensenada los Choros, and estero San Rafael.

The Parque Nacional Marino Archipielago de San Lorenzo south of Angel de la Guarda was declared in 2005 (Diario Oficial de la Federación 2005). Its purpose is to protect native species at risk (Diario Oficial de la Federación 2001), particularly the blue whale (*Balaenoptera musculus*), humpback whale (*Megaptera novaeangliae*), sperm whale (*Physeter macrocephalus*), loggerhead turtle (*Caretta caretta gigas*), green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricate*), olive Ridley turtle (*Lepidochelys olivacae*), and totoaba. The protected area encompasses about 580 km^2 of land and sea and includes three nuclear zones: Zona Marine del Complejo Insular Partido y Partida, Zona Marina Complejo Insular Rasito y Rasa, and Zona Marina Complejo Insular Las Animas y San Lorenzo.

The San Pedro Martir Biosphere Reserve was declared in 2002 (Diario Oficial de la Federación 2002). It encompasses 300 km^2 and surrounds Isla San Pedro Martir in the central gulf 61 km southwest of Punta Kino, Sonora, and 55 km east of Punta San Gabriel, Baja California. It includes a small nuclear zone extending approximately 1.7 km east and 1.7 km south of the island. The Area de Proteccion de Flora y Fauna Islas del Golfo de California is a terrestrial reserve encompassing about 3,800 km^2, including San Esteban Island about 12 km southwest of Isla Tiburón.

Fisheries

Fisheries in the northern Gulf of California consist of a large industrial shrimp trawling sector based out of Puerto Peñasco, Guaymas, and San Felipe, Baja California. Artisanal fisheries are pursued by between 9,000 and 18,000 pangas currently operating in the Gulf of California (Guerrero-Ruíz et al. 2006), with more than 1,300 vessels in the northern gulf distributed among 17 permanent fishing communities (Moreno-Baez 2010); approximately 3,800 people are active in these small-scale fisheries in the study region (Turk-Boyer unpubl. data). The region is subject to a high rate of industrial fishing, mainly for penaeid shrimp species in the north and central gulf, and high rates of artisanal fishing targeting mainly rocky reef fish species, elasmobranchs, and benthic invertebrates.

Trawls

The largest and most valuable fishery in the Gulf of California is the shrimp trawl fishery that operates in the northern gulf targeting brown shrimp (*Farfantepenaeus californiensis*), white shrimp (*Litopenaeus vannamei*), and blue shrimp (*Litopenaeus stylirostris*). The shrimp fishery is important to Mexico; on the Pacific coast it generates more than $5 billion annually (SAGARPA 2002), with fisheries in the northern gulf contributing more than $130 million annually to the local economy and employing about 30,000 people directly and indirectly (Guerrero-Ruíz et al. 2006, Lluch-Cota et al. 2007). As much as 80% of the catch is exported, so this fishery plays an important role in Mexico's foreign exchange (Magallón-Barajas 1987). Some 103 active licenses are authorized in Puerto Peñasco, where the bulk of fishing activity occurs (Perez-Valencia unpubl. data). Large industrial vessels conduct the trawl fishery; they are typically 50 feet in length, powered by 220–620 hp inboard diesel engines, and use twin trawl nets up to 50 feet wide with a 6 cm mesh size (Meltzer and Chang 2006). Typical of trawl fisheries, the industrial northern gulf shrimp trawl fishery is associated with high levels of bycatch and may cause damage to benthic structures (Flanagan and Hendrickson 1976, Nava-Romo 1994, Cisneros-Mata et al. 1995). The fishery operates from September to March.

Gill Nets

Other fisheries in the northern gulf include inshore gill net fisheries operated from pangas targeting drums and croakers (corvina–Sciaenidae) and using 3.5 inch mesh.[2] This fishery operates year-round. Another inshore gill net fishery targets rays (Rajidae) and guitarfish (Rhinobatidae) using 5–6 inch mesh. It operates from December to May. An offshore pangas gill net fleet targets mackerel (Spanish mackerel [*Scomberomorus concolor*] and sierra mackerel [*S. sierra*]) between July to August (D'Agrosa et al. 1995). During the off-season, large shrimp trawl vessels are adapted for an offshore gill net fishery targeting small migratory sharks (Triakidae) using a 4-inch mesh, operating from January to August. There are seven active licenses for this fishery in Puerto Peñasco, San Felipe, and Golfo Santa Clara (Perez-Valencia, unpublished data).

Smaller artisanal pangas boats also target shrimp from September to April using demersal monofilament drift nets (called chinchorro de linea) with a mesh size of 7 cm or less (D'Agrosa et al. 1995). There are 450 licenses authorized for this activity in Puerto Peñasco, San Felipe, and Golfo Santa Clara, but an equal number of pangas operate unlicensed (Turk-Boyer unpubl. data). This is due to a lack of monitoring and enforcement, and constitutes a major source of illegal, unreported, and unregulated catch in the northern gulf. Panga vessels also operate a midwater finfish trawl fishery from December to April; 20 licenses are authorized in the towns of Puerto Peñasco, San Felipe, and Golfo Santa Clara (Perez-Valencia unpubl. data).

Hook and Line

Longline fisheries (cimbra) operating from pangas pursue primarily gulf coney (*Epinephelus acanthistius*), goldspotted sand bass (aka extranjero [*Paralabrax auroguttatus*]), parrot sand bass (*P. loro*), drums and croakers, groupers (Serranidae), and snappers (Lutjanidae). The fishery operates from October to April. Widespread artisanal handline fisheries occur year-round targeting various reef fish species (Cudney-Bueno and Turk-Boyer 1998). The northern gulf also supports a lucrative angling fishery that targets primarily large pelagic fish (sailfish [*Istiophorus platypterus*], yellowfin tuna [*Thunnus albacares*] and mahi mahi [*Coryphaena hippurus*]) and reef fish (mainly groupers) (Aburto-Oropeza et al. 2008a). During the peak tourist season, 20–40 recreational fishers (5–8 pangas) depart San Felipe daily; the price of the charter is about 1,200 pesos per week of fishing per person.[3]

Stationary Gear

Trap fisheries operated from pangas target blue crab (*Callinectes bellicosus*) between July and May, predominantly in the northeast region of the gulf. There is also an octopus trap fishery located near Guaymas (Danemann and Ezcurra 2007). Fish traps are used to capture extranjero, groupers, and other reef fish species between November and April along the eastern coast of the gulf. Finally, a compressor diving (hooka) fishery takes a variety of invertebrates from inshore areas including scallops and penshells, bivalves, sea cucumbers, sessile

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[2] R. Loaiza-Villanueva, CEDO, Puerto Peñasco, Sonora, México. Pers. commun., March 2008.

[3] O. Aburto-Oropeza, Scripps Institution of Oceanography, Univ. California San Diego, La Jolla, CA. Pers. commun., September 2008.

invertebrates, and snails as well as fish. This fishery operates year-round in the northeastern area of the Gulf. Subsistence gleaning for fish and invertebrates is also common throughout the Gulf.

Methods

Atlantis

Atlantis is a deterministic biogeochemical and biophysical modeling system that simulates the structure and functioning of marine ecosystems. Ecosystems are resolved spatially in three dimensions, with the study area divided into polygons; simulation dynamics follow a 12-hour time step. Biotic ecosystem components are typically represented in functional groups: groups of species aggregated according to life history, feeding, or niche similarities. Subroutines represent nutrient nitrogen flows throughout groups, consumption, production, waste production, migration, recruitment, habitat dependency and mortality, including predation, senescence, and fishery removals.

The Atlantis ecosystem modeling framework is based on Bay Model 2 (Fulton 2001, Fulton et al. 2004a), which was itself inspired by two other ecosystem models and incorporates some of their successful elements: the Integrated Generic Bay Ecosystem Model (Fulton et al. 2004b) and the Port Phillip Bay Integrated Model (Murray and Parslow 1999). Socioeconomic submodels in Atlantis are described by Fulton et al. (2007b). The current version of Atlantis as of this publication date has some undocumented revisions relating to model structure, but a preliminary technical manual has recently been developed (Kaplan unpubl. manuscr.). Reviews of Atlantis and similar marine ecosystem modeling approaches are provided by Plagányi (2007), Cury et al. (2008), and Jørgensen (2008). Discussion on the effects of ecosystem model structure and variable aggregation is available in Metcalf et al. (2008), Pinnegar et al. (2005), Fulton et al. (2003), and Fulton et al. (2004c).

Model Structure

What follows is a brief summary of the relationships in Atlantis critical to the northern Gulf of California modeling effort. For a more complete description of the Atlantis model, refer to Fulton (2004a); that document details how Atlantis handles additional nutrient types, ocean and sediment chemistry, bacterial and detrital loops, and other refinements. Parameterization of the northern Gulf of California model is described below under the Northern Gulf of California Model subsection.

Primary producer dynamics

Atlantis uses the primary producer groups: seagrass, macroalgae, and large and small phytoplankton. Growth of these groups is driven by Michaelis-Menten dynamics in which maximum growth rate asymptotes in accordance with nutrient, light, and space limitations. Biomass is lost to predation, lysis, linear and quadratic mortality, and harvesting. The rate of change in biomass B for a primary producer group is

$$dB/dt = G - M - \sum_{j=1}^{n} M_j - F \tag{1}$$

in which G is growth rate of autotroph, M is natural mortality not explicitly captured in the model (see below), M_j is predation mortality due to grazer j, n is number of grazers, and F is mortality due to harvesting; and where the rate of growth is defined as

$$G = \mu \cdot \delta_{irr} \cdot \delta_N \cdot \delta_{space} \cdot A \tag{2}$$

where μ is maximum growth rate, δ_{irr} is light limitation factor, δ_N is nutrient limitation factor, δ_{space} is space limitation factor, and A is rate of catabolism. For formulation of the limitation factors, δ_{irr}, δ_N, and δ_{space}, see Fulton et al. (2004a), as it varies between producers.

Nutrients

Nutrient concentrations affect the growth rate of primary producers through the δ_N term. Rates of change for ammonia (NH) and nitrate (NO) are given as

$$\frac{d(NH)}{dt} = -\sum_{i=1}^{P} A_{NH,i} + \sum_{j=1}^{C} E_{NH,j} - S + R \tag{3}$$

$$\frac{d(NO)}{dt} = -\sum_{i=1}^{P} A_{NO,i} + S \tag{4}$$

where A is rate of uptake of NH or NO from the water column by autotroph i, P is set of all autotrophs, E is excretion of NH by consumer j, C is set of all consumers, S is amount of NH converted to NO by bacteria (nitrification), and R is amount of NH produced by denitrification.

Consumer biomass dynamics

All vertebrate functional groups are divided into 10 age-classes and Atlantis tracks abundance and weight for each age-class. Abundance is described for vertebrates in terms of the number of individuals per map polygon, the structural nitrogen weight per individual (mg sN/individual), and the reserve nitrogen weight per individual (mg rN/individual). Structural nitrogen represents hard body parts such as bones and teeth, while reserve nitrogen represents somatic and gonadal soft body tissue. Atlantis represents invertebrates and primary producers as biomass pools on a per-volume basis for pelagic invertebrates and infaunal invertebrates (mg N • m^{-3}) and a per-area basis for epibenthic invertebrates (mg N • m^{-2}). Simplifying, changes in biomass for vertebrate or invertebrate consumers are tracked according to equation 5,

$$dB/dt = G - \sum_{i=1}^{n} M_i - M + I - F \tag{5}$$

where biomass (B) is substituted by abundance per age-class in the case of vertebrate consumers, M_i is mortality due to predator i, n is number of predators, M is mortality not captured by predator-prey dynamics (see below), I is immigration into model domain, and F is fishing mortality.

Note that the units for growth (G) are biomass per unit time; G is defined as

$$G = \sum_{i=1}^{n} P_i \cdot \varepsilon_i \cdot \delta_{O_2} \cdot \delta_{space} \tag{6}$$

where P_i is predation by consumer on prey i, ε_i is assimilation efficiency on prey i, δ_{02} is oxygen limitation factor, and δ_{space} is space limitation factor.

For vertebrates, growth is allocated further into structural and reserve nitrogen pools using relationships in Fulton et al. (2004a). Calculation of predation (P) on prey i by predator j (in biomass per unit time) may take on a variety of forms in Atlantis, such as the modified version of the Holling Type II functional response (Holling 1959)

$$P_{ij} = \frac{B_i \cdot a_{ij} \cdot B_j \cdot C_j}{1 + \frac{C_j}{G_j}\left(\sum_{i=1}^{n} B_i \cdot a_{i,j} \cdot E_{ij}\right)} \tag{7}$$

where B_i is biomass of prey I, B_j is biomass of predator j, C_j is clearance rate of predator j, G_j is growth rate of predator j, E_{ij} is growth efficiency of predator j eating prey I, and a_{ij} is availability of prey i to predator j.

The availability parameters establish the rates of flow of material between functional groups. The parameters can be calculated from a diet matrix that describes the diet composition of each predator group for a time point, such as the model's initial conditions. The functional response allows these diet compositions to vary through time, thus considering density-dependent effects relating to varying abundance of prey items. Feeding rates also vary dynamically according to gape limitation. The gape-limited feeding routine directs predation mortality to prey groups and age-classes that fall within a practical size range, determined as a fraction of predator body weight.

The routine is sensitive to the feeding mode of the predator; for example, predators that bite have access to a wider size range than those that rely on suction feeding. Finally, predation rate will be affected by spatiotemporal segregation of predator and prey. The availability parameter determines the maximum contribution of prey to the diets of predators, but maximum feeding rates will only be achieved if prey and predator coinhabit the same polygons and depth layers. Thus predation refuges can be captured in the map design, while rates of feeding respond to seasonal and diel movement patterns. Further explanation of feeding dynamics is available in Fulton et al. (2004a) and Kaplan et al. (2009).

Natural mortality

Natural mortality (M) not captured in Atlantis through predator-prey dynamics is calculated for group (i) as

$$M_i = M_{lin,i} \cdot B_i + M_{quad,i} \cdot B_i^2 + M_{special} \tag{8}$$

In the case of vertebrates, the biomass term B is replaced by abundance. Natural mortality for group i is composed of density-independent linear mortality (M_{lin}), density-dependent quadratic mortality (M_{quad}), and special mortality terms specific to certain groups (e.g., to represent mechanical stress on macroalgae, fouling by epiphytes on seagrass, oxygen limitation on benthic consumers, and starvation for vertebrate consumers).

Other dynamics

Other processes described in Fulton (2001) and Fulton et al. (2004a) include waste production and removal, population dynamics of dinoflagellates and bacteria, sediment chemistry, animal movement, and vertebrate reproduction.

Northern Gulf of California Model

The Gulf of California model encompasses approximately 57,800 km^2 of sea area and includes the Colorado River estuary in the northern gulf to areas as far south as the northern tip of Baja California Sur. The southern edge of the study area connects with the southern Gulf of California at the latitude of Salinas (Baja California Sur) in the west and Tastiota (Sonora) in the east. The study area is delimited by the following coordinates: north lat 31°49′35.98″N, west long 114°53′47.05″W, south lat 27°53′36.25″N, and east long 111°27′14.56″W. The Midriff Islands (Angel de la Guarda and Tiburón) are represented as land polygons, while other small islands and island chains, such as the San Lorenzo Archipelago and Isla San Pedro Martir, are represented as shallow sea areas in which the presence of land is implicit. Fleet activity, species migration patterns, and oceanography are represented in the base state of the Atlantis simulation as they occur on January 1. This period corresponds to the cool season when primary production is high and major fisheries are active (Hidalgo-Gonzáles and Alvarez-Borrego 2001).

Functional Groups

Biological groups in Atlantis[4] are typically functional groups, though individual species are possible, with the number of groups specified by the user up to a fixed maximum number of hard-wired functional group "slots" including 35 age-structured (typically vertebrate) groups (e.g., fish, mammals, and reptiles), 11 pelagic invertebrate groups (of which 2 are split into juvenile and adult ontogenetic stanzas), 7 epibenthic invertebrate groups, 5 primary producer

[4] A new version of Atlantis being written will relax these constraints, but that version was not available for use in this work.

groups, and 3 nonliving groups. Chalcraft and Resetarits (2003) provide comment on the advantages and difficulties in assigning functional groups for ecological studies.

Fish Group Composition

The fish species for the northern Gulf of California model are presented in Appendix A, Table A-1. There are 576 species identified as being present in the study area. This list was compiled from a number of sources: it includes all fish species listed in the FishBase (Froese and Pauly 2007) internet database (http://www.fishbase.org/home.htm) as occurring in the Gulf of California (area code 165 in the ecosystem table), which accounts for 62% of species. A fraction of these are expected to occur only in the southern part of the gulf, but their influence on group parameters will be negligible since we calculated group parameters using a weighted average method based on relative abundance.

The remaining species represent those identified in the Tropical Eastern Pacific Species database (Robertson and Allen 2002), which are recorded by FishBase to occur in Mexico (country code 484) and also have occurrence records in the FishBase database within the northern Gulf of California, bounded by the following coordinates: lat 28.5° to 32.0°N, long 111°30′ to 115°W. Further, we included reef fish species identified in Appendix 1 of Thomspon et al. (2000), PANGAS transect observations[5] and the PANGAS commercial species list outlined for the action and monitoring plans (PANGAS Planes de Manejo).[6] Spelling and taxonomic variations among these lists were standardized in Table A-1 to match the FishBase format with respect to the valid name field of the species table.

Invertebrate Group Composition

Invertebrate species for the northern Gulf of California model are presented in Table A-2. The species list representing invertebrates that occur in the northern Gulf of California was compiled from the Listado y Distribucion de la Macrofauna del Golfo de California described by Findley and Brusca (2005). That resource provides a list of more than 4,900 invertebrate species identified in the Gulf of California. In order to identify which species occur in the northern gulf, we used latitude/longitude fields provided in the database, which demark a polygon representing the range extent and the distribution field, which categorizes areas of occurrence. In order to be included, the species distribution field had to mention one or more of the following areas: northern gulf (data code: GCN), central gulf (data code: GCC), upper Gulf of California, and Colorado River Delta Biosphere Reserve (data codes: BR and RB). The short list that resulted was further reduced to include only species whose distribution overlapped with the following area range: lat 28.5° to 32.0°N, long 111°30′ to 115°W, which represents the approximate dimensions of the northern gulf study area. Approximately 3,491 species of invertebrates are therefore identified as occurring in the study area.

[5] S. Perez-Valencia, CEDO, Puerto Peñasco, Sonora, Mexico. Pers. commun., October 2008.
[6] R. Cudney-Bueno, David and Lucile Packard Foundation, Los Altos, CA. Professional observ., May 2008.

Length and Weight

To standardize information in FishBase and other sources, a generic set of conversions were used to obtain total length (TL) for fish. This was necessary for length-weight calculations and to develop an average fish length for adult classes (e.g., in order to utilize empirical formulae described below, develop a maturation schedule, set gape restriction, and for other purposes). To convert fork length (FL) to TL, we used the linear empirical relationships of Booth and Isted (1997); the relationship employed is based on panga (*Pterogymnus laniarus*), as

$$TL = (FL - 0.6848) / 0.901 \quad (9)$$

For fish with emarginated tails, the relationship is based on the lesser gurnard (*Chelidonichthys quekerri*) as

$$TL = (FL - 3.6166) / 0.9454 \quad (10)$$

All pelagic, benthopelagic, and bathypelagic fish were assumed to have forked tails, while all reef fish, demersal, and bathydemersal fish were assumed to have emarginated tails. Each species is demarked into one of these six habitat classifications according to data indicated in the habitat field of the FishBase species table. Where standard length (SL) was provided, the conversion factor to TL was applied from Christensen and Pauly (1992) as

$$TL = 1.1757 \bullet SL - 0.1215 \quad (11)$$

Asymptotic Weight

W_∞ is the asymptotic fish body weight in grams. The parameter is used in calculation of natural mortality of fishes (below) and in determination of average body weights through use of a dynamic pool model, which converts fish abundance data from transects into biomass densities (dynamic pool model is explained below in the subsection Theses and technical documents). W_∞ was taken directly from FishBase, if it was available in the "aveWinf" field of the PopGrowth table or the "Winf" field of the QB table. Where no value was available from FishBase, the parameter was calculated from a length-weight (L/W) relationship (Equation 12), using a and b growth parameters found respectively in the "a" and "b" fields of the FishBase PopGrowth table, and L_∞. L_∞ is taken preferentially from the "aveLinf (TL)" field of the PopGrowth table.

$$W = a \bullet L^b \quad (12)$$

L/W parameters from the following groups were provided by the PANGAS species sample database (Cudney-Bueno et al. 2007): gulf coney, extranjero, leopard grouper (*Mycteroperca rosacea*), barred pargo (*Hoplopagrus guentherii*), Pacific red snapper (*Lutjanus peru*), and croaker (*Ophioscion strabo*). Further field sampling conducted for this volume analyzed the following taxa: white seabass (*Atractoscion nobilis*), finescale triggerfish (*Balistes polylepis*), Pacific porgy (*Calamus brachysomus*), jacks (*Caranx* spp.), Pacific golden-eyed tilefish (*Caulolatilus affinis*), ocean whitefish (*C. princeps*), corvinas (*Cynoscion* spp.), diamond stingray (*Dasyatis dipterura*), gulf cony, California butterfly ray (*Gymnura marmorata*), barred pargo, gulf croaker (*Micropogonias megalops*), striped mullet (*Mugil cephalus*), smoothhounds (*Mustelus* spp.), gulf grouper (*Mycteroperca jordani*), leopard grouper, spotted sand bass

(*Paralabrax maculatofasciatus*), sand bass (*Paralabrax* spp.), halibut and flounders (*Paralichthys* spp.), Pleuronectidae, California skate (*Raja inornata*), Pacific sierra (*Scomberomorus sierra*), California sheephead (*Semicossyphus pulcher*), bullseye puffer (*Sphoeroides annulatus*), and puffers (*Sphoeroides* spp.). Finally, Alfredo Arreola (unpubl. data) sampled an additional 115 species and 20 higher order taxa. The length-weight relationships presented by these combined data sources are provided in Appendix B, Table B-1, Figure B-1, and Figure B-2. If any of these L/W parameters were unavailable, then W_∞ was instead estimated from the maximum weight (W_{MAX}), which occurs in the "Max weight" field of the FishBase Species table, according to the rule-of-thumb equation (Ainsworth et al. 2007).

$$W_{MAX} = W_\infty \bullet 0.95 \tag{13}$$

Age Distribution

The initial age structure was assumed to resemble an equilbrium distribution for all functional groups. Survivorship at age for mammals, birds, and turtles was estimated using Siler's competing risk model modified by Barlow and Boveng (1991) (Ortiz unpubl. data). This method requires estimates of longevity (the number of years until 1% of the population remains). These were set as follows: vaquita (20 years), pinnipeds (16.3 years), mysticeti (76 years), reef associated turtles (52 years), odontocetae (39 years), orcas, also known as killer whales (*Orcinus orca*), (50 years), and birds (26 years). These longevities were determined from sources cited in Horne et al. (2009).

This method divides the mortality schedule into three phases, in which the youngest phase and oldest phase have high mortality rates and the intermediate phase has a relatively low mortality rate. Fish numbers at age were assumed to follow an exponential decay curve, where total mortality was assumed equal to natural mortality (M) for unexploited functional groups, and equal to 2M for exploited groups. For fish, M was taken directly from literature sources or FishBase (data in Table A-4, references in Table A-5). Where an estimate could not be found from literature, the regression equation of Pauly (1980) was used to determine M (equation 14), which requires temperature in degrees celsius (T) and growth information: the von Bertalanffy growth constant (K) and the asymptotic length at infinity (L_∞). These values were obtained for most species from the FishBase PopGrowth table. When L_∞ was unavailable, the maximum specimen length observed L_{MAX} was substituted, assuming that $L_\infty = 0.95 \bullet L_{MAX}$.

$$M = K^{0.65} \bullet L_\infty^{-0.279} \bullet T^{0.463} \tag{14}$$

Reproduction

Atlantis explicitly models the reproductive schedule of functional groups using the following variables: spawning time (i.e., mid-point of spawning window: Atlantis variable _Time_Spawn), spawning window duration (_spawn_period), recruitment time (i.e., mid-point of recruitment window: _Recruit_Time), and recruitment window duration (_Recruit_Period). Values for the Gulf of California model (Figure 2 and Table A-8) were set based on community interview information collated in CEDO and COBI fisheries information brochures that were assembled for distribution to fishing communities (Turk-Boyer unpubl. data, Torre unpubl.

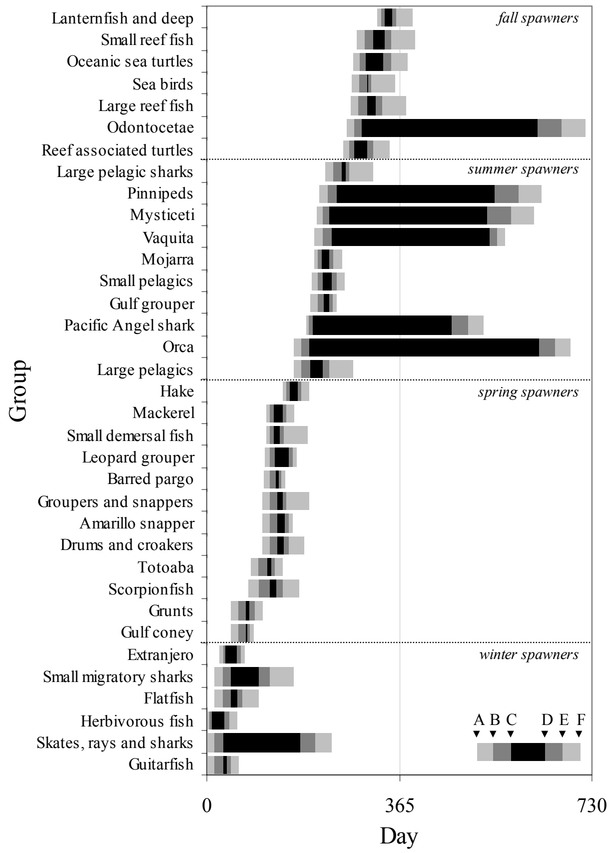


Figure 2. Spawning and recruitment schedule. A) beginning of spawn window, B) spawn date (_Time_Spawn), C) end of spawn window, D) beginning of recruitment window, E) recruitment date (_Recruit_Time), and F) end of recruitment window.

data), from expert communications,[7] and from literature (DeCraene and Fink 2004, WWF 2008). The period between spawning and recruitment (black in Figure 2) corresponds to larval duration in the case of spawners (e.g., demersal and pelagic teleosts), gestation in the case of live-bearers (e.g., mammals, elasmobranchs), or incubation in the case of egg-layers (e.g., birds, turtles), while recruitment corresponds to settling, birth, or hatching for these groups, respectively.

Beverton-Holt recruitment was assumed for all fish in the model except elasmobranchs. Elasmobranchs, mammals, birds, and turtles were assumed to reproduce according to a fixed recruitment relationship, where each female produces a fixed number of viable progeny per year (i.e., progeny that survive the implicit larval, gestation, or incubation period). Recruitment parameters (e.g., alpha/beta in the Beverton-Holt stock recruitment relationship or the fixed number of offspring) are critical tuning parameters for Atlantis and were changed widely in adjusting model dynamics. The initial Beverton-Holt parameters were based on values used by Brand et al (2007), averaged across functional groups to the level of species guilds, and applied

[7] R. Loaiza-Villanueva, Centro Intercultural de Estudios de Desiertos y Oceanos, Puerto Peñasco, Sonora, Mexico. Pers. commun., September 2008.

to similar groups in the northern gulf. During tuning these were changed by factors given in Table 1. Recruitment parameters for groups with fixed recruitment are presented in the species descriptions along with references and assumptions.

Availabilities Matrix

The matrix of availability parameters (*a* in equation 7) for the northern Gulf of California model was built using a stand-alone calculator developed by Gamble (unpubl. manuscr.). The program calculates parameters of the functional response based on an input matrix representing the percent contribution of prey species to predators' diet (where each element represents an annual average taken over the entire study area). Other parameters required to calculate availabilities include population growth rates, biomass concentrations of predator and prey, ecotrophic efficiencies, and consumption rates (i.e., clearance rates in Atlantis). To construct the input diet matrix needed by the calculator, we consulted literature where available, used logical rules to assign diets (especially to data-poor juvenile groups), and initiated a fish gut content

Table 1. Recruitment parameters for fish groups.

		Guild value from Brand et al. (2007)		Changes made during model tuning (multiplication factor)		Value used in model	
Functional group	**Species guild**	**Alpha**	**Beta**	**Alpha**	**Beta**	**Alpha**	**Beta**
Lanternfish and deep	Deep demersals	1.00E+08	8.05E+12	72	1	7.20E+09	8.05E+12
Scorpionfish	Deep piscivores	3.41E+08	8.44E+12	0.733	1	2.50E+08	8.44E+12
Herbivorous fish	Estuarine demersals	1.91E+11	2.42E+13	4.08E-04	1	7.80E+07	2.42E+13
Flatfish	Flat deep demersals	5.79E+06	7.24E+10	75.993	0.6	4.40E+08	4.34E+10
Large reef fish	Large piscivores	2.31E+05	1.98E+08	8.225	10	1.90E+06	1.98E+09
Gulf coney	Large piscivores	2.31E+05	1.98E+08	3.733	1	8.62E+05	1.98E+08
Gulf grouper	Large piscivores	2.31E+05	1.98E+08	2.598	0.1	6.00E+05	1.98E+07
Extranjero	Large piscivores	2.31E+05	1.98E+08	1.221	1	2.82E+05	1.98E+08
Leopard grouper	Large piscivores	2.31E+05	1.98E+08	3.034	1	7.01E+05	1.98E+08
Amarillo snapper	Large piscivores	2.31E+05	1.98E+08	5.195	1	1.20E+06	1.98E+08
Barred pargo	Large piscivores	2.31E+05	1.98E+08	0.398	1	9.20E+04	1.98E+08
Groupers and snappers	Large piscivores	2.31E+05	1.98E+08	86.866	1	2.01E+07	1.98E+08
Totoaba	Large piscivores	2.31E+05	1.98E+08	1.342	1	3.10E+05	1.98E+08
Mackerel	Mesopelagics	8.00E+08	1.54E+11	0.004	1	2.84E+06	1.51E+11
Blue crab	Crabs	9.00E+13	2.00E+09	1.00E-08	1	9.00E+05	2.00E+09
Blue shrimp	Prawns	9.00E+13	2.00E+09	1.00E-08	1,000	9.00E+05	2.00E+12
Small demersal fish	Shallow demersals	3.22E+08	4.28E+11	50.547	1	1.63E+10	4.28E+11
Mojarra	Shallow piscivores	6.31E+06	8.76E+06	45.254	1	2.86E+08	8.76E+06
Small reef fish	Shallow piscivores	6.31E+06	8.76E+06	206.022	1	1.30E+09	8.76E+06
Drums and croakers	Shallow piscivores	6.31E+06	8.76E+06	71.589	1	4.52E+08	8.76E+06
Grunts	Shallow piscivores	6.31E+06	8.76E+06	9.192	1	5.80E+07	8.76E+06
Hake	Small planktivores	3.00E+11	5.90E+11	0.001	1	3.00E+08	5.90E+11
Small pelagics	Small planktivores	3.00E+11	5.90E+11	0.067	1	2.00E+10	5.90E+11
Large pelagics	Tuna	5.04E+07	4.91E+11	0.015	1	7.70E+05	4.91E+11

study in the northern Gulf of California to fill in information gaps and provide local data for major exploited species. Table 2 shows a summary of the data sources used to estimate Atlantis functional group availabilities. The rules used for assigning diet compositions to juvenile fish groups based on the diet of adult groups are as follows:

- Diet contribution of fish prey decreased by 5%, difference goes to small zooplankton.
- 50% of the diet contribution of adult prey items was assigned to juvenile prey items.
- 25% of the diet contribution of large zooplankton prey items was assigned to small zooplankton prey items.
- 25% of diet contribution of large phytoplankton prey items was assigned to small phytoplankton prey items.
- 50% of the diet contribution of large reef fish prey items was assigned to small reef fish prey items.
- 50% of the diet contribution of large pelagics prey items was assigned to small pelagics prey items.
- The diet contribution of adult blue crab prey items was assigned to juvenile blue crab prey items.
- The diet contribution of adult blue prawn prey items was assigned to juvenile blue prawn prey items.

In tuning the 1985 model to data, we made extensive ad hoc adjustments to the availabilities matrix, resulting in the final matrix (Figure 3 and Table A-9), which was subsequently transferred to the 2008 model. This assumes that prey preference and prey vulnerabilities were constant between periods. However, it does not assume that the feeding rates were constant. As described earlier in the Consumer biomass dynamics subsection, dietary contributions will vary dynamically in Atlantis according to gape size feeding limitations, changes in the relative proportions of predator and prey abundance, and spatiotemporal segregation of predator and prey.

Fish gut content analysis

The field sampling and laboratory analysis protocol for the gut content study is provided in Appendix C; this document helped direct technicians from CEDO and COBI who carried out the sample collection and laboratory analysis. We then used a statistical method to combine the field sampling results with available diet information from FishBase and literature. The methodology and results are presented in Ainsworth et al. (2010). A summary follows.

The statistical method used to analyze gut contents collected for this study involved bootstrapping the stomach content data to create statistical distributions describing the likely contribution of each prey item to the diets of predators. Both predator and prey were resolved at the level of Atlantis functional groups. For each predator, these distributions were fit to a Dirichlet function, which is the multinomial generalization of the beta function. Each prey item contributing to the diet of a given predator corresponds to an axis in the Dirichlet function. After finding the best-fit Dirichlet parameters using a MATLAB 6.1 (The Mathworks, Natick,

Table 2. Origin of diet data for Atlantis functional groups. Groups composed of multiple species may use several data sources.

Group	Data source*	Group	Data source*
Gulf coney	Juveniles, 4; adults, 2	Vaquita	Juveniles, 5; adults, 5
Extranjero	Juveniles, 4; adults, 1	Pinnipeds	Juveniles, 5; adults, 5
Leopard grouper	Juveniles, 4; adults, 3	Oceanic sea turtles	Juveniles, 3; adults, 3
Gulf grouper	Juveniles, 4; adults, 2	Reef associated turtles	Juveniles, 3; adults, 3
Amarillo snapper	Juveniles, 4; adults, 3	Sea birds	Juveniles, 3; adults, 3
Barred pargo	Juveniles, 4; adults, 2	Benthic bacteria	3
Groupers and snappers	Juveniles, 4; adults, 2	Scallops and penshells	3
Drums and croakers	Juveniles, 4; adults, 1	Penaeid shrimp	3
Grunts	Juveniles, 4; adults, 2	Sea cucumbers	3
Herbivorous fish	Juveniles, 4; adults, 1	Sessile invertebrates	3
Large reef fish	Juveniles, 4; adults, 1	Crabs and lobsters	3
Small reef fish	Juveniles, 4; adults, 1	Herbivorous echinoderms	3
Small demersal fish	Juveniles, 4; adults, 1	Carnivorous macrobenthos	3
Pacific angel shark	Juveniles, 4; adults, 2	Inf. Epi. meiobenthos	3
Small migratory sharks	Juveniles, 4; adults, 1	Bivalves	3
Large pelagic sharks	Juveniles, 4; adults, 3	Snails	3
Guitarfish	Juveniles, 4; adults, 2	Blue crab	Juveniles, 4; adults, 3
Skates, rays, sharks	Juveniles, 4; adults, 1,2,3	Labile detritus	NA
Flatfish	Juveniles, 4; adults, 1	Refractory detritus	NA
Mojarra	Juveniles, 4; adults, 2	Macroalgae	NA
Scorpionfish	Juveniles, 4; adults, 2	Pelagic bacteria	3
Lanternfish and deep	Juveniles, 4; adults, 2	Large phytoplankton	NA
Totoaba	Juveniles, 3; adults, 3	Small phytoplankton	NA
Large pelagics	Juveniles, 4; adults, 1,2	Blue shrimp	Juveniles, 3; adults, 3
Mackerel	Juveniles, 4; adults, 1	Seagrass	NA
Hake	Juveniles, 4; adults, 3	Jellyfish	3
Small pelagics	Juveniles, 4; adults, 2	Large zooplankton	3
Mysticeti	Juveniles, 5; adults, 5	Squid	5
Odontocetae	Juveniles, 5; adults, 5	Small zooplankton	3
Orca	Juveniles, 5; adults, 5	Microphytobenthos	NA
		Carrion detritus	NA

*Data source (NA = not applicable):

1. Maximum likelihood method (Ainsworth et al. 2010).
2. Simple average of predator stomachs from field sampling.
3. Literature values (see group descriptions).
4. Based on adult using rules on juvenile diets.
5. From previous Ecopath with Ecosim (EwE) models (see group description).

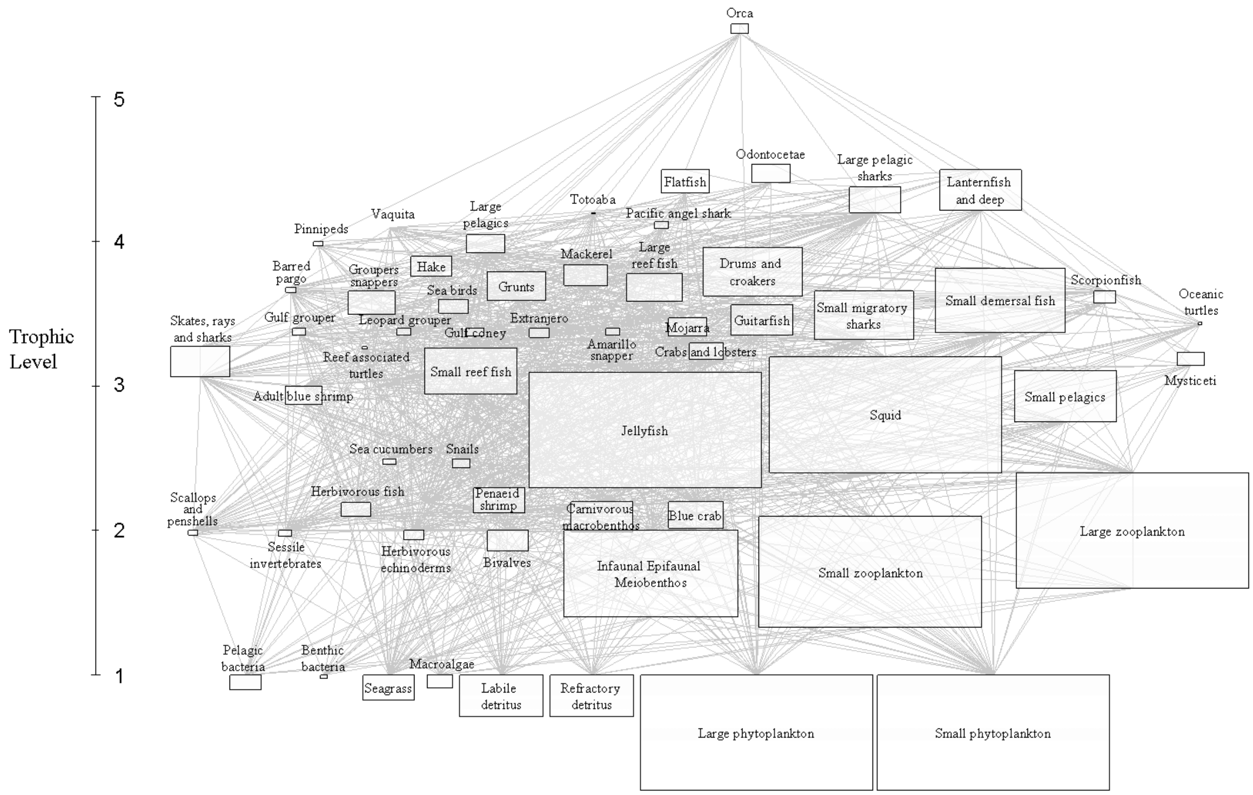


Figure 3. Food web diagram showing complete connectance present in availabilities matrix. Y dimension shows trophic level. Areas of boxes are directly proportional to group biomass, except for small and large phytoplankton, jellyfish, squid, and large zooplankton, which were reduced in size. Prey connect from top of box; predators connect from bottom of box.

Massachusetts) algorithm in the Fastfit Toolbox, the maximum likelihood estimate (MLE) was made from each marginal beta distribution. The MLE represents the contribution of a certain prey item to the diet of the predator, while confidence intervals of the marginal beta distribution reflect the error on this point. Ainsworth et al. (2010) provide a full description of the method.

The main advantage of using this statistical fitting method, for example, as opposed to using a simple averaging method in which the contribution of prey to a predator's diet is taken as the mean of all available stomachs, is that the statistical method discounts the importance of rare feeding events in determining the diet composition of the predator. It is therefore a more robust method for use with small stomach data sets, or when predators are known to feed on prey with patchy spatial distributions. The statistical method also allows us to estimate the confidence range of the final diet composition.

In addition to field sampling, the statistical method integrated data from FishBase (Froese and Pauly 2007), the PANGAS PDF database maintained by the University of Arizona,[8] previous Ecopath with Ecosim (EwE) models of the Gulf of California (Arreguín-Sánchez et al. 2004, Morales-Zárate et al. 2004, Zetina-Rejón et al. 2004, Diaz Uribe et al. 2007), and other

[8] A. Cinti, Univ. Arizona, Tucson. Pers. commun., April 2008.

literature sources reported in the appendices of Ainsworth et al. (2010). Diet information was taken from the FishBase diet data table. The useful information was contained in fields FoodIII, FoodIII2 through FoodIII10, and DietP1 through DietP10, which provide the identity and percent composition of analyzed prey items, respectively.

Migrations

Vertical migrations

Atlantis allows explicit modeling of diel vertical migration. For invertebrate functional groups (large zooplankton, squid, and jellyfish), the vertical movement pattern was set according to references cited in the Functional group descriptions subsection below. Fish vertical position (all functional groups) was set according to the following rules. For each species in the functional group, the vertical position mode in the water column was determined according to the DemersPelag field of the FishBase species table as bathydemersal, bathypelagic, benthopelagic, demersal, pelagic, or reef associated. The mode was said to refer to the daytime position of adults; the vertical distribution used for each mode is presented in Table 3. The overall position for the functional group was then taken as a weighted average of the constituent species, so if a functional group consists of mainly demersal species, for example, the vertical positioning of that group would most closely reflect the demersal mode.

The nighttime distribution for the adults of pelagic species was scattered vertically and distributed slightly more towards the surface depth layers, while the nighttime distribution of adults of demersal and reef-associated species was set identically to the daytime distribution, assuming that they undergo no diel migrations. The daytime distribution of juveniles somewhat reflects the adult distribution, but is orientated strongly towards the bottom depth layers. The nighttime distribution of juveniles is orientated strongly to the surface layers.

Seasonal movement inside model domain

The northern Gulf of California Atlantis model represents seasonal movement within the model domain, such as onshore-offshore spawning migrations. All functional groups were said to follow one of seven movement patterns. Pattern 1 implies there is no seasonal movement (all four seasons have same biomass distribution); this distribution follows the adult pattern derived in the Method 1: Biomass allocation algorithm subsection below. Pattern 2 represents a

Table 3. Vertical daytime position for adult fish.

		Vertical position modes					
Location	**Depth layer**	**Bathy-demersal**	**Bathy-pelagic**	**Bentho-pelagic**	**Demersal**	**Pelagic**	**Reef-associated**
Sediment	1	0.4	0.3	0.2	0.8	—	1.0
	2	0.4	0.3	0.3	0.2	—	—
	3	0.2	0.1	0.2	—	—	—
	4	—	0.1	0.1	—	0.05	—
	5	—	0.1	0.1	—	0.15	—
Surface	6	—	0.1	0.1	—	0.80	—

temperature-driven distribution, where individuals migrate inshore during winter and into deeper areas during summer. Pattern 3 indicates a breeding profile, where individuals migrate inshore during spring and offshore during summer. Pattern 4 is an alternate breeding profile, where individuals migrate inshore to east coast esturaries, rhodolith, and seagrass beds during spring and offshore during summer. Pattern 5 indicates individuals move north during spring and south during fall. Pattern 6 is a static distribution (all seasons same) and applies to juveniles only, where individuals remain in shallow inshore areas year-round. Pattern 7 is a static distribution and applies to juveniles only, where individuals remain in east coast estuaries year-round. For Pattern 7, the biomass distribution of functional groups is directly proportional to the area coverage of estuarine habitat (Glenn et al. 2006).

Movement patterns assigned to functional groups are provided in Table 4. Reef fish groups were assumed to be sedentary; there is no migration in unlisted invertebrate groups. For aggregated groups consisting of many species, only part of the population was said to migrate. General movement patterns were informed by expert opinion.[9] Atlantis polygons to 80 m depth (i.e., polygons including one or two depth layers) were considered shallow; polygons greater than 80 m (i.e., including three or more depth layers) were considered deep; polygons adjacent to land were considered inshore and other polygons were considered deep.

Migration outside of model domain

To capture the highly seasonal nature of the northern gulf and related large-scale migrations of species, our Atlantis model explicitly includes migration into and out of the model domain. This is set according to the seasonal movements of functional groups described in the Functional group descriptions subsection below. Adult stanzas of the following groups undergo these movements: small migratory sharks, large pelagic sharks, totoaba, large pelagics, mackerel, Pacific hake (*Merluccious productus*), mysticeti, odontocetae, pinnipeds, oceanic sea turtles, reef associated turtles, and sea birds. The portion of the population migrating out of the model domain was assumed to originate from all occupied polygons; the amount each polygon contributes is directly related to its biomass concentration.

2008 Model Biomass Initialization

Relative abundance and biomass data for the present-day (2008) model were extracted from several key sources. These include reef transect studies conducted by the PANGAS project, an inshore trawl sampling program by NWFSC and CEDO designed to support the Atlantis model, peer-reviewed literature and expedition reports, stock assessment by the Mexican fisheries authority INAPESCA, theses, and other technical documents. This subsection details the techniques and assumptions used to translate these data sets into biomass density estimates for initialization of Atlantis. Biomass densities used to initialize the 2008 model are presented by polygon and functional group in Table B-3 through Table B-7. Functional group descriptions below provide detailed accounts of data sources and assumptions.

[9] R. Loaiza-Villanueva, CEDO, Puerto Peñasco, Sonora, Mexico. Pers. commun., March 2008.

Table 4. Seasonal movement pattern for functional groups.

Group	Adult pattern	Juvenile pattern	Fraction of adult population migrating
Gulf coney	3	7	1.0
Gulf grouper	3	7	1.0
Leopard grouper	4	7	1.0
Drums and croakers	5	6	1.0
Barred pargo	4	7	1.0
Amarillo snapper	4	7	1.0
Herbivorous fish	1	6	—
Extranjero	1	7	—
Large reef fish	1	7	—
Small reef fish	1	6	—
Small demersal fish	1	6	—
Pacific angel shark	1	1	—
Guitarfish	2	6	0.5
Flatfish	2	6	0.5
Large pelagic sharks	1	1	—
Mojarra	1	1	—
Skates, rays, sharks	3	1	0.5
Pinnipeds	1	1	—
Sea birds	1	1	—
Oceanic sea turtles	1	1	—
Large pelagics	5	1	0.5
Lanternfish and deep	1	1	—
Mackerel	5	6	0.5
Hake	5	1	1.0
Small pelagics	1	6	—
Reef associated turtles	1	1	—
Mysticeti	1	1	—
Odontocetae	1	1	—
Vaquita	1	1	—
Orca	1	1	—
Groupers and snappers	1	7	—
Grunts	1	6	—
Small migratory sharks	5	1	1.0
Scorpionfish	1	1	—
Totoaba	1	1	—
Adult blue crab	1	1	—
Adult blue shrimp	3	6	0.5

PANGAS reef transects

From May to July 2007, the PANGAS project conducted scuba reef transect studies at 25 sites in the northern gulf, including the Midriff Islands, mainland Sonora, and Islas Encantadas, with the purpose of describing annual and spatial variability in fish community structure (Torre unpubl. data). Three sampling methods were used at each site: a transect study determined the abundance of fish in a known volume of the water column, a swath study determined the abundance of macroinvertebrates in a known area of the seabed, and a point-contact study determined substrate composition. We provide a brief summary here of the sampling methods,[10] and we describe how biomass data was processed for use in the Atlantis model. See PANGAS (2008) for additional information.

For the scuba reef transect study, each site was sampled in two adjacent areas and at four depth strata (5, 10, 15, and 20 m isobaths) to describe the fish assemblage. Paired divers swam along the bottom and the mid water column counting the number of fish seen within a 2 x 2 m wide window over a distance of 30 m. Volume sampled was therefore 120 m^3 for each depth category, or 240 m^3 total at each site.[11] Divers recorded the species identification and body length of all identifiable noncryptic species (i.e., all species except gobies, blennies, and triplefins), as well as physical data such as depth. Using the body length data and length-weight parameters obtained from PANGAS sampling (Table B-1), FishBase, and other sources (Table A-3 and Table A-4), we determined the body weight of each sighted fish using equation 11. Summing species weight by functional group, dividing by the volume swept, and combining the two depth categories provided an estimate of biomass per unit volume of water, which we assumed could be applied on a per-area basis for the seafloor. The rocky areas selected for sampling are known to be excellent fishing sites and may overestimate typical abundance of fish species.[12] We accounted for this in determining biomass concentrations for Atlantis functional groups (Method 1: Biomass allocation algorithm subsection below).

Macroinvertebrate biomass was determined in PANGAS sampling using swaths. The swath method recorded the number of invertebrates greater than 2.5 cm in length occurring on a 60 m^2 area of the sea floor (2 x 30 m). Two such transects were conducted in each of three depth zones. To apply this information to the Atlantis model, we determined the number of individuals per functional group occurring per square meter of seafloor and converted to biomass using average individual weights available in Nava-Romo (1994). Individual weights were calculated at the functional group level, so some custom adjustments were made for large species; for example, anemones were considered heavier than other organisms in the sessile invertebrate functional group. PANGAS swath data also included an adjustment for individual size. Individuals designated as large were assumed to weigh twice as much as typical organisms in the same functional group; individuals designated as small were assumed to weigh 50% as much.

A third transect method was used in the PANGAS sampling program. Point-contact sampling helped determine substrate cover at 60 intervals evenly spaced along 30 m transects. The same locations were sampled as in the fish transect and swath studies. Divers noted sediment type or biogenic structure, but this information was too fine scale to be of use in setting Atlantis habitats.

[10] M. Rojo, COBI, Guaymas, Sonora, Mexico. Pers. commun., 4 June 2008.
[11] Data sheets for this protocol were incorrect; in reality six 30 x 2 x 2 m transects per depth were sampled. Therefore the biomass concentration analysis used a smaller area than the actual area sampled (240 m^3 versus 720 m^3). This could result in an overestimation of biomass for certain functional groups; however, several data sources were consulted in each biomass estimate, thus potential errors are minimized.
[12] S. Perez-Valencia, CEDO, Puerto Peñasco, Sonora, Mexico. Pers. commun., 22 May 2008.

Isla San Pedro Mártir reef transects

Reef transect efforts were also made by the University of Arizona and COBI in areas around Isla San Pedro Mártir (ISPM) in 2001 through 2005 and in 2007 (Torre unpubl. data). Three types of sampling methods were used. Linear dive transects were employed to estimate the abundance of a select number of commercial fish species, point counts conducted in observational columns by stationary divers were used to estimate abundance of a wider variety of fish including noncommercial species (biodiversity study), and linear transects were used to count the number of benthic invertebrates. Protocols used in sampling are in preparation (Rojo unpubl. manuscr.).

The linear dive transects for commercial species allowed observers to assess the abundance of 16 fish taxa around 17 sampling locations near ISPM. Observations were made to a maximum depth of 33 m; 250 m^2 of sea floor were covered in each transect. Fish counts were converted into biomass densities using an area-swept method assuming an average individual body weight per species. The individual weights were determined based on body lengths reported by divers in the ISPM studies; these were converted to weights using equation 11 with species-level parameters from FishBase and other sources (Table A-3).

In the biodiversity study, the abundance and individual size of 104 fish species were determined using observation cylinders, where divers counted fish within a fixed radius. Twenty-one sampling locations were tested around ISPM to depths of 32 m; each dive covered 170 m^2 of sea floor. Biomass densities were estimated using an area-swept method, converting average body lengths from diver observations to body weight using species-specific length-weight relationships. For species whose lengths were not available from ISPM observations, we used an age-structured Beverton-Holt model to determine body size at equilibrium under assumed fishing mortalities, natural mortalities from equation 13, and life history parameters (data, Table A-3; references, Table A-4 and Table A-5).

The point count method allows a greater variety of species to be sampled than the line transect method, but likely introduces a bias as large fish with fast swimming speeds avoid divers in the narrow observational column before they can be counted (Torre unpubl. data). Comparison between the results of ISPM linear transects and observational columns suggest that this may be true (Figure 4), as larger fish are more frequently counted in linear transects. For this reason, we assumed biodiversity counts comprised low-quality data for large reef associated functional groups (extranjero, leopard grouper, gulf grouper, amarillo snapper, barred pargo, and groupers/snappers), and weighted these data points at half-value in determining biomass concentrations (see Method 1: Biomass allocation algorithm subsection below).

Finally, dive transects provided abundance estimates for 49 invertebrate species including echinoderms and mollusks (bivalves and gastropods). Nineteen sites were sampled near ISPM to a maximum depth of 31 m; each transect covered 25 m^2. Counts were converted to biomass using an area-swept method and assumed an average weight per individual. The length-weight relationship of pearl oyster (*Pinctada mazatlanica*) is based on a regression model by Saucedo and Monteforte (1998) and the average weight of sea cucumbers (*Isostichopus fuscus*) is informed by a W_∞ value offered by Herrero-Perezrul et al. (1999). For remaining species we calculated body weight (W) from length (L) using a simple cubic relationship ($W = B \bullet L^3$),

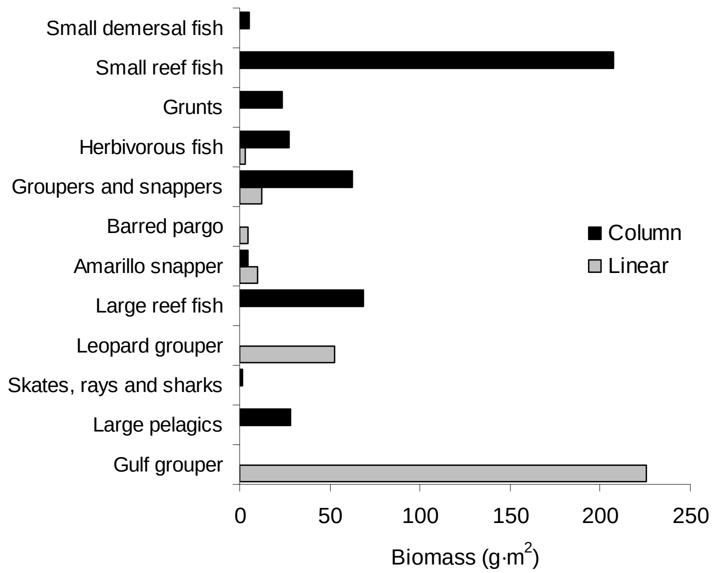


Figure 4. Biomass determined using observational columns versus linear transects. Sampling locations are around Isla San Pedro Martir (2002–2007). Fish functional groups are sorted by length, with fish size (L_∞) increasing towards the bottom.

where B is the conversion ratio 2 g • cm^{-3}. Where body length was unavailable, we assumed the following body weights, making some individual exceptions for larger organisms: gastropods, 20 g; mollusks, 80 g; and echinoderms, 100 g.

Scripps reef transects

Unpublished data from 2008 dive transect work in Bahia de Los Angeles were available from the Scripps Institute of Oceanography at the University of California, San Diego (Paredes unpubl. data). Fish count data was converted to biomass density using an area-swept method, and assuming similar individual body weights as fish found in the PANGAS reef transect study (described above). Of the approximately 24,000 individual fish identified in the Scripps sampling, we were able to apply species-specific body weights to 94%. For species not sighted in the PANGAS study, we assumed average body weights at the level of families and functional groups based on PANGAS reef transect results.

Theses and technical documents

The following documents were used to help determine biomass concentrations for fish and invertebrate functional groups: Nava-Romo (1994), Thomson and Mesnick (1993), Thomson et al. (1996) and Gilligan (1980). Additional biomass data points were located in Aburto-Oropeza et al. (2009), Cruz-Romero (1996), and Casas-Valdez and Ponce-Diaz (1996).

Nava-Romo (1994) summarized shrimp trawl bycatch information at 19 sites in the northeastern part of the Gulf of California in waters adjacent to San Jorge. He provided biomass estimates for 70 species and genera of fish and 15 species and genera of invertebrates. The information contributed to 18 Atlantis fish functional groups and 8 invertebrate groups. We were able to determine average biomass densities per site for winter and early spring using an area-swept method. We calculated area based on the total area covered per month and the corresponding number of sites sampled per month.

Information in Thomson and Mesnick (1993) allowed us to calculate approximate biomass densities for 28 invertebrate species, contributing to 3 Atlantis functional groups. We estimated biomass densities for invertebrates from counts of individuals by assuming the following body weights: 100 g for Asteroidea, Echinoidea, and Ophiuroidea and 400 g for Holothuroidea. Swimming speed of divers was assumed to be 5 km • h^{-1}, and the survey cone was assumed to encompass 2 m on each side of the diver, which allowed us to crudely estimate an area swept based on dive duration.

Thomson and Mesnick (1993) also provided a relative ranking of abundance for 60 fish species, contributing to 11 Atlantis fish functional groups, as sampled at 7 sites at the mid and lower Gulf of California. They used abundant, common, uncommon, and rare as description categories. Assigning ranks 1 through 4 for these categories and summing these species-level values by functional group provides a proxy for relative biomass. A static multiplier was used to convert the proxy index to absolute biomass in such a way as to minimize discrepancies versus PANGAS transect data aggregated to the functional group level. Because of the numerous assumptions required to utilize this data, we considered this information low-quality, and assigned half value weighting for these data points in determining biomass concentrations (see Method 1: Biomass allocation algorithm subsection below).

Thomson et al. (1996) determined biomass estimates for 61 fish species contributing to 9 Atlantis fish functional groups. Those authors surveyed eight sites between Bahia de Los Angeles and Guaymas, including several minor islands around the Midriff Islands and within the San Lorenzo archipelago biosphere reserve. To convert their count data to biomass, we employed the following methods. Average weight of individual fish by species was estimated using a Beverton-Holt age-structured dynamic pool model. von Bertalanffy growth parameters (L_{∞}, k, t_0), length-weight parameters (a, b), weight at infinity (W_{∞}), and age at maturity used for this are collated in Table A-3. Natural mortality was determined by the process described in the Natural mortality subsection above. Where species-level information was unavailable, parameters were set as the average of all species occurring in the Atlantis functional groups.

The model assumed fishing mortality of 0.5 yr^{-1} for all species belonging to the following exploited groups: groupers and snappers, leopard grouper, barred pargo, amarillo snapper, large reef fish, and herbivorous fish. A fishing mortality rate of 0.2 yr^{-1} was assumed for remaining species, which belong to the following lightly exploited groups: small reef fish, small demersal fish, scorpion fish, and grunts. Knife edge entry to the fishery was assumed to occur at the age of maturity. As we did not have an estimate of the area covered by divers with which to determine a biomass density, we assumed they covered 536 m^2; this is the area that would minimize discrepancies against reef fish biomass densities determined using PANGAS 2007 dive transect data, as measured by the sum of squared residuals across functional groups common to the two data sets. This is equivalent to the area covered by a diver swimming 4 km • h^{-1} for 4 minutes and monitoring a 2-meter swath.

Trawl and longline sampling

In calculating species biomass densities for the Atlantis model, we had sufficient data regarding rocky reefs from the PANGAS, ISPM, and Scripps reef transect studies detailed above. For soft-bottom areas, we had adequate information concerning deepwater habitats from analyses of shrimp trawl bycatch, particularly from Nava-Romo (1994), described above. However, we were lacking information on the soft-bottom assemblage in the nearshore. NWFSC therefore initiated a trawl and longline sampling program to help address this data gap.

The trawl and longline sampling protocol is presented in Appendix C. CEDO technicians conducted the sampling along the north and northeastern coasts of the gulf. Since the study was limited to using a hand-drawn net, all sampling occurred at depths of less than 12 m. Fifteen sandy bottom sites were sampled in March and again in September to elucidate any seasonal differences in the species assemblage. Locations for sampling were selected using a semirandom procedure. The separations between sampling sites were chosen to fall between 10 and 30 km; sites were selected randomly with equal probability and ArcMap (ESRI ArcGIS geographical information system) was used to select coordinates along the shoreline corresponding to those separations. Where rock or substrate unsuitable for trawling was encountered or where the beach was inaccessible by road, the sampling site was relocated further away from Puerto Peñasco (the central location) until a suitable area was reached.

Four trawl tows and three longline sets were conducted at each site in an alternating arrangement (Figure 5). The positions of trawl tows and longlines were also selected randomly using a uniform distribution so that 100–250 m separated each tow and the same distance separated each longline. The trawl tows began near shore and extended offshore perpendicular to the beach for several kilometers or to a maximum of 12 m depth. Vessel speed was constant at 5 km • h^{-1}, and total distance traveled depended on the duration of the tow, which varied from 10 to 15 minutes depending on the amount of biomass encountered at that site. The position of the longline sets relative to shore varied randomly between three locations: nearshore, 900 m, and 1,800 m. These were chosen randomly for each set with equal likelihood. Any on-site variations made to the sampling protocol were recorded and accounted for in later biomass calculations.

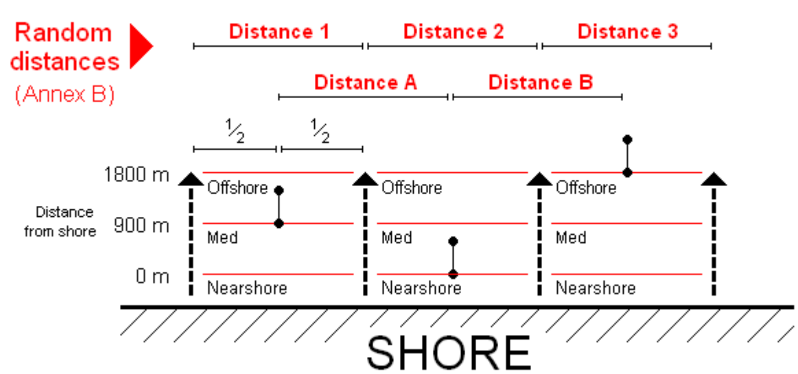


Figure 5. Trawl and longline survey design. Distances 1, 2, 3, A, and B were chosen randomly within limits.

An earlier protocol called for a 6-foot rigid beam trawl, but low catch rates in a pilot study led researchers to suspect vessel avoidance behavior by fish was occurring. The revised protocol therefore used a 16-foot otter trawl, which showed improved catch rates. We used an underwater camera system to further investigate vessel avoidance and provide an estimate of catchability.

The purpose of deploying longlines was to determine whether there were large fish present in the study area that may be able to avoid the trawl net. Deployment of longlines was eventually discontinued in the sampling program since very few fish were caught, relative to the trawl, despite attempts to optimize hook size, bait size, and soak time. Expert opinion lead us to assume that large fish typically did not come close to shore in the soft-bottom habitats being sampled,[13] and therefore the lack of large fish in the trawl data is likely due to their preference for deeper habitats, rather than their avoidance of our nearshore, shallow trawls.

Comparison of all biomass data sources

The sources described above provided biomass information for 24 vertebrate functional groups and 13 invertebrate groups (Figure 6). Biomass for the remaining groups (11 vertebrate and 15 invertebrate) was estimated from species-specific articles (see Functional group descriptions subsection below) and from published EwE models for the Gulf of California: Morales-Zárate et al. (2004), Lozano (2006), and Arreguin-Sánchez et al. (2002); EwE, Christensen and Pauly (1992), Walters et al. (1997).

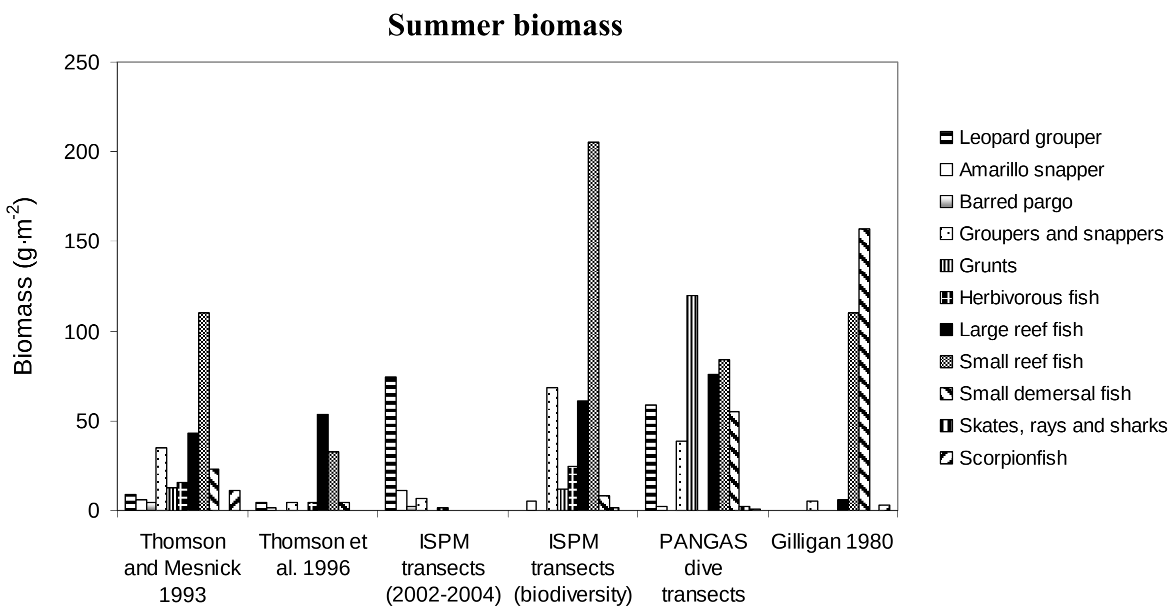
Spatial Biomass Distributions

Method 1: Biomass allocation algorithm

The data sources described above most often provided point estimates of biomass at certain locations throughout the gulf. We devised a biomass allocation algorithm to extrapolate those estimates to other areas. The procedure can be summarized as follows. The entire northern gulf study region was divided into a grid of points 10 km apart (Figure 7). A similarity matrix was constructed to describe how similar the environment at each grid point is to each available sample or transect location. The biomass concentration at each grid point was then determined as a weighted average of all sampling locations, where similar sampling locations contributed more to the weighted average and dissimilar sampling locations contributed less. Various filters specific to each functional group were then used to refine the biomass distributions. Biomass concentrations at each grid point were then averaged to the polygon level.

The similarity matrix considers biological and physical factors: absolute distance from sample to grid point, proximity to shore of sample versus that of grid point, substrate type, and season of sampling. For each functional group, the biomass concentration (B) at each grid point (i) was determined according to

[13] See footnote 1.



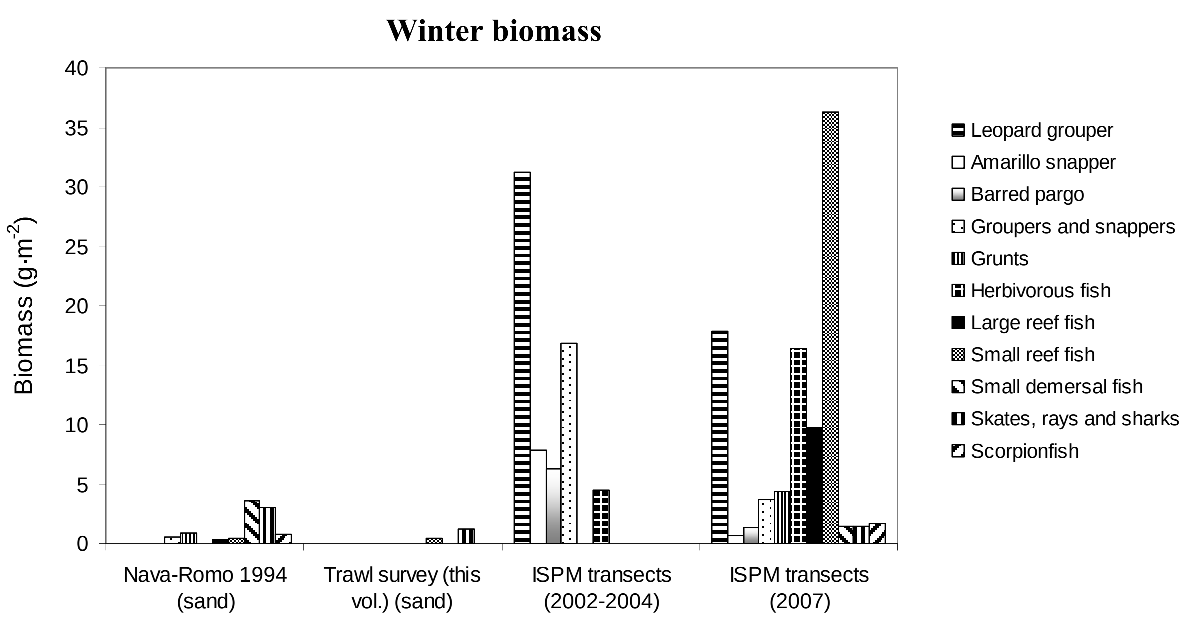


Figure 6. Seasonal fish biomass estimates from PANGAS sampling and literature values.

$$B_i = \frac{\sum_J B_j \cdot W_{i,j,g} S_1 S_2}{\sum_J W_{i,j,g} S_1 S_2} \tag{15}$$

where B_j represents biomass concentration at sampling location j, J is the total number of sampling locations, and S_1 and S_2 are scaling factors representing, respectively, a correction factor to adjust the biomass concentration at sites known to be high in abundance (90%) and a

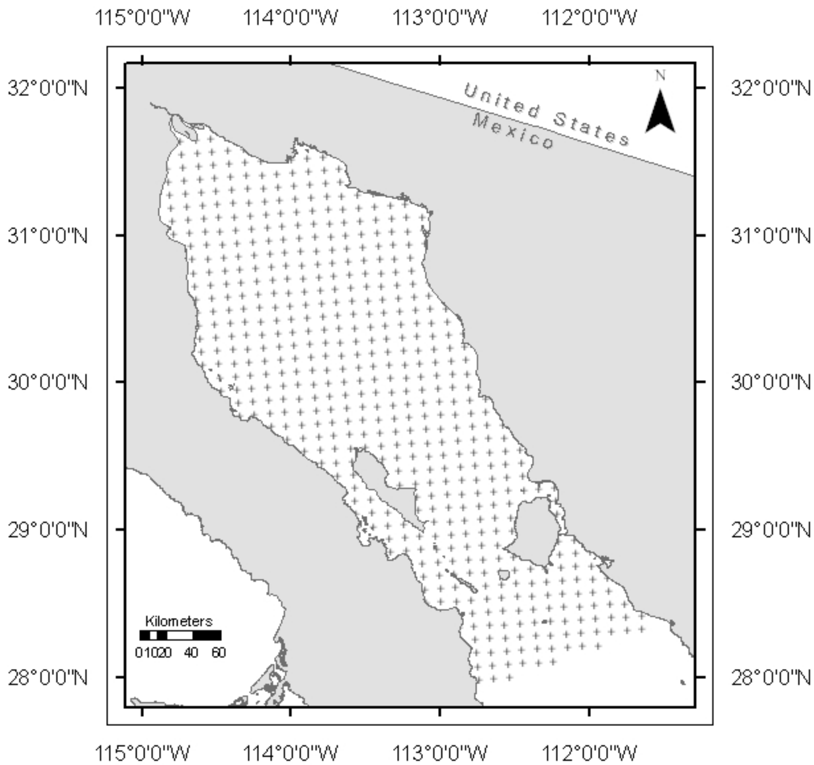


Figure 7. Grid points used for transect biomass allocation algorithm.

correction factor to represent the relative mesoscale coverage of rock in the "rocky" areas indicated on PANGAS sediment maps (20%). The weighting factor $W_{i,j,g}$ represents the relative similarity between grid point i and sampling location j for functional group g, as determined by

$$W_{i,j,g} = \frac{W_S W_{ps} W_{qg} W_{sub}}{D^{\theta}} \tag{16}$$

The seasonal weighting factor (W_S) is dependent on the season of the sampling (S_j) (classified as either spring/summer or fall/winter) and the season of the grid point (S_i), which is always fall/winter (model start date is January 1). The weighting factor that represents proximity to shore (W_{ps}) depends on the proximity to shore (ps) for each grid point and sample, categorized as being less than 10 km or greater than 10 km. Weighting factors are defined in equation 17.

$$W_S = \begin{cases} 1 & \text{if } S_i = S_j \\ 0.5 & \text{otherwise} \end{cases} \quad \text{and} \quad W_{ps} = \begin{cases} 1 & \text{if } ps_i = ps_j \\ 0.8 & \text{otherwise} \end{cases} \tag{17}$$

For low-quality data sources identified in the preceding sections, weighting for data quality (W_q) was set equal to 0.5 with respect to each relevant functional group (g); for high-quality data, W_q was set equal to 1. The substrate weighting factor (W_{sub}) was determined from the following matrix.

	Grid point (*i*)		
Sample (*j*)	Rock	Sand	Mud
Rock	1.0	0.4	0.1
Sand	0.4	1.0	0.5
Mud	0.1	0.4	1.0

In this way, a sample taken over rock is considered more similar to a sandy grid point than a muddy grid point. The corresponding substrate map is provided in Figure 8.

The absolute distance (*D*) from the sample point to the grid point is used as a scaling factor so that samples taken near a grid point will have a stronger influence in determining the biomass concentration at that grid point than samples taken from further away. The exponent θ (0.146) was chosen so that a sample taken 100 km away from a grid point would have half the influence of a sample adjacent to the grid point.

We passed an additional filter based on depth over the grid points to discern whether a given functional group occurs at a particular location. For each species in each functional group, the depth range occupied was taken from the species table in the FishBase database. Pelagic species were assumed to occur in all depth zones. The depth range occupied by functional groups was considered inclusive of all member species' ranges. Comparing the occupied range of each functional group to the depth value at each grid point allowed us to assign simple presence or absence.

The locations at which deepwater reef-associated functional groups occur were further constrained to only areas identified as fishing zones in PANGAS interviews (Figure 9) (Moreno-Báez et al. 2010). The areas where deepwater reefs were assumed to occur are based on the combined fishing areas for extranjero, giant sea bass (*Stereolepis gigas*) and gulf coney. Three Atlantis functional groups, gulf coney, extranjero and lanternfish/deep fish, were assumed to occur only in those identified fishing areas, while one functional group, large reef fish, was assumed to concentrate in those areas. For large reef fish, the biomass concentration in fished areas was set at 150% relative to unfished areas. Since this is an aggregated group, it is likely some member species occur outside these fishing areas.

The locations at which shallow water reef-associated functional groups occur were similarly constrained according to the fishing area utilization patterns developed from PANGAS interview materials. The fishing locations of the following species were used to determine the approximate locations of shallow water reefs: white seabass, jacks, corvina (*Cynoscion* spp.), spotted cabrilla (*Epinephelus analogus*), barred pargo, amarillo snapper (*Lutjanus argentiventris*), Pacific red snapper, gulf grouper, sawtail grouper (*Mycteroperca prionura*), leopard grouper, spotted sand bass, and sierra. Fishing areas for these species were overlapped and a 2 km buffer zone was added to ensure that the (relatively small) fishing areas would intersect with a minimum number of grid points (Figure 9).

We assumed these fished areas represent favorable habitat and we assigned a biomass concentration of 200% relative to unfished areas; this value is present in the initialization of Atlantis, but will equilibrate to a more stable configuration upon simulation. The PANGAS fishing area utilization study provides the best available resource for estimating the location of

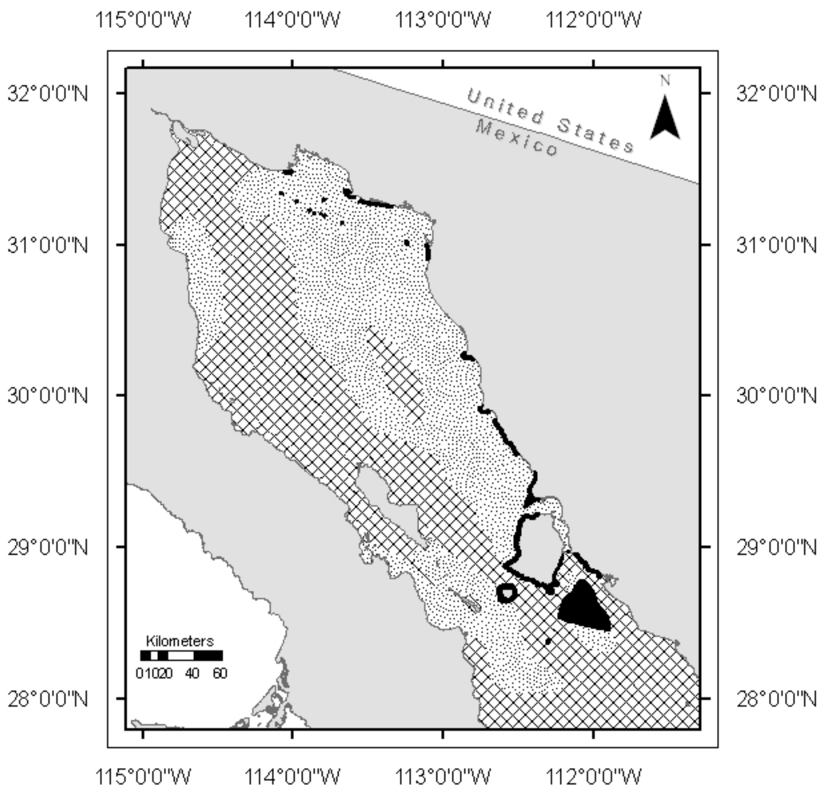


Figure 8. Substrate map supporting transect biomass allocation algorithm; rock (solid black), mud (cross-hatch), and sand (fine dots) (Moreno-Baez unpubl. data).

rocky reefs, as no comprehensive survey has been conducted in the northern gulf.[14] The biomass allocation algorithm yielded functional group association by substrate type as in Figure B-3 and Figure B-4 and biomass density per polygon as in Figure B-5 through Figure B-9.

Method 2: FishBase habitat affinities

Some functional groups were not identified in the available reef transect and trawl sampling data, so the optimized biomass allocation could not be used to allocate their spatial distribution. For these groups, species-level habitat affinities from FishBase were used to resolve the relative spatial distribution of biomass, then the absolute biomass was set through other means (see species descriptions). In various fields of its ecology table, FishBase categorizes the habitat preference for each fish species in terms of presence or absence. Fields were selected that represent environments occurring in the northern gulf: esturaries, intertidal, soft, rocky, oceanic, neritic, seagrass, and macrophyte. Each Atlantis polygon was scored to represent the relative area coverage for each habitat type, and the cross product of the polygon and habitat affinity matrices formed a biomass distribution map. The coverage of estuaries is based on Glenn et al. (2006), coastal polygons are considered intertidal, polygons consisting of four or more depth layers are considered oceanic, and polygons consisting of one or two depth

[14] R. Cudney-Bueno, David and Lucile Packard Foundation, Los Altos, CA. Professional observ., 18 August 2008.

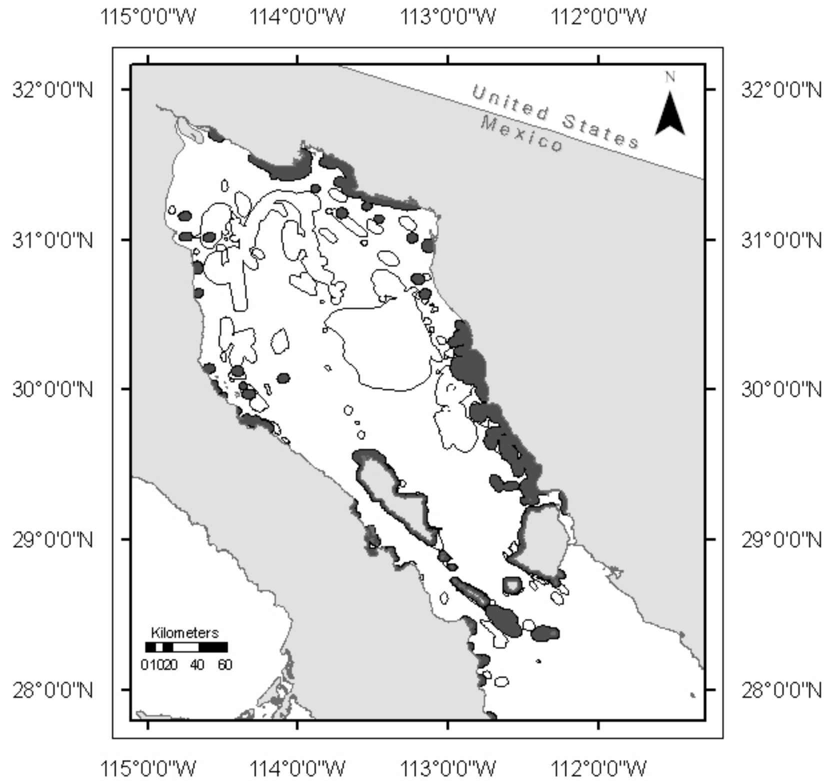


Figure 9. Fishery utilization areas: shallow reef species (solid gray areas) and deep reef species (white areas). Sources: PANGAS interviews and Moreno-Baez et al. (2010).

layers are considered neritic (see Table 5). Rock, soft, seagrass, and macrophyte areas are based on expert knowledge summarized in Moreno-Baez (unpubl. data). For nonfish vertebrate species (mammals, birds, and turtles) habitat distributions were set manually to reflect known aggregation sites.

Assigning spatial distributions

Functional groups' initial spatial distributions were set using the biomass allocation algorithm, FishBase habitat affinities, a weighted combination of these two methods, a published distribution, or some simpler algorithm (e.g., uniform distribution, in coastal polygons only, proportional to other groups, or manually set). The method employed for each functional group is listed provided in Table 6. Alternative methods for assigning a spatial distribution, for example, based on geostatistical techniques, are available but require more information such as spatial catch per unit effort (CPUE) data (e.g., Ruiz-Luna et al. 2010).

Relative Abundance Time Series

One useful and largely untapped resource for generating relative abundance time series is LEK held by fishers and community members (Johannes et al. 2000). Although there are many examples of where LEK has been collected and used in study and in management, few examples exist of where such data are used quantitatively (e.g., Ainsworth et al. 2008a, Anadón et al. 2009,

Table 5. Polygon physical characteristics.

Polygon	Area (km^2)	Depth layers	Productivity	Max depth (m)	BotZ	Area coverage (%)			
						Reef	Soft	Canyon	Eddy
0	372.7	4	Oceanic	500	–400	0	100	0	29.2
1	1,262.0	4	Oceanic	500	–400	0	100	0	29.2
2[a]	152.8	4	Oceanic	500	–400	1.6	98.4	0	7.3
3	760.5	6	Oceanic	2,025	–1,620	0	40	60	29.2
4	340.8	4	Oceanic	500	–400	0	100	0	29.2
5	660.5	3	Oceanic	150	–120	72.9	27.1	0	29.2
6	1,046.1	2	Shelf	80	–64	22.4	77.6	0	7.3
7[b]	227.3	4	Oceanic	500	–400	0	85	15	29.2
8[b]	295.7	4	Oceanic	500	–400	0	85	15	29.2
9[b]	38.8	4	Shelf	500	–400	0	100	0	29.2
10[b]	82.8	4	Oceanic	500	–400	0	100	0	29.2
11	168.1	2	Shelf	80	–64	56.1	43.9	0	29.2
12	318.3	4	Oceanic	500	–400	0	100	0	29.2
13	339.1	2	Shelf	80	–64	30.7	69.3	0	7.3
14[b]	23.7	4	Shelf	500	–400	0	100	0	29.2
15[c]	1,085.1	0	—	—	0	0.5	99.5	0	29.2
16[b]	37.1	4	Shelf	500	–400	0	100	0	29.2
17	761.7	6	Oceanic	2,025	–1,620	0	50	50	58.5
18	375.0	4	Oceanic	500	–400	0	90	10	29.2
19	597.1	4	Oceanic	500	–400	0	90	10	29.2
20	502.9	1	Shelf	25	–20	11.3	88.7	0	7.3
21	538.6	4	Oceanic	500	–400	0	100	0	29.2
22[d]	925.6	0	—	—	0	0	100	0	29.2
23	614.5	5	Oceanic	1,000	–800	0.1	99.9	0	29.2
24	274.2	3	Oceanic	150	–120	0	100	0	29.2
25	591.7	2	Shelf	80	–64	0.7	99.3	0	29.2
26	7,661.7	3	Oceanic	150	–120	0	100	0	7.3
27	4,798.6	4	Oceanic	500	-400	1.6	98.4	0	7.3
28	577.0	1	Shelf	25	–20	24.5	75.5	0	29.2
29	143.9	4	Oceanic	500	–400	0	95	5	29.2
30	292.8	4	Oceanic	500	–400	0	100	0	29.2
31	1,094.5	5	Oceanic	1,000	–800	0	80	20	58.5
32	302.0	4	Oceanic	500	–400	0	95	5	29.2
33	4,822.2	4	Oceanic	500	–400	0	100	0	58.5
34	3,485.5	4	Oceanic	500	–400	1.6	98.4	0	7.3
35	527.7	3	Oceanic	150	–120	0	100	0	29.2
36	500.5	1	Shelf	25	–20	0	100	0	29.2
37	806.1	2	Shelf	80	–64	0	100	0	29.2
38	155.6	2	Shelf	80	–64	2.6	97.4	0	7.3
39	178.9	1	Shelf	25	–20	13.3	86.7	0	7.3
40	185.0	2	Shelf	80	–64	0	100	0	7.3
41	186.8	1	Shelf	25	–20	0	100	0	7.3
42	1,740.8	3	Oceanic	150	–120	0	100	0	58.5
43	1,087.4	2	Shelf	80	–64	0	100	0	58.5
44	212.1	1	Shelf	25	–20	0	100	0	29.2
45	1,396.7	4	Oceanic	500	–400	1.6	98.4	0	7.3
46	105.8	2	Shelf	80	–64	0	100	0	7.3
47	81.1	1	Shelf	25	–20	0	100	0	7.3
48	357.0	1	Shelf	25	–20	6.8	93.2	0	29.2
49	2,601.2	2	Shelf	80	–64	1.2	98.8	0	29.2
50	1,837.8	2	Shelf	80	–64	0	100	0	58.5
51	328.0	1	Shelf	25	–20	0	100	0	29.2

Table 5 continued. Polygon physical characteristics.

Polygon	Area (km^2)	Depth layers	Productivity	Max depth (m)	BotZ	Area coverage (%) Reef	Soft	Canyon	Eddy
52	3,059.4	3	Oceanic	150	–120	0	100	0	58.5
53[e]	27.0	1	Oceanic	25	–20	6.8	93.2	0	29.2
54	168.3	1	Shelf	25	–20	0	100	0	29.2
55	501.1	1	Shelf	25	–20	15	85	0	29.2
56	471.4	3	Oceanic	150	–120	26.1	73.9	0	7.3
57[f]	1,281.8	2	Shelf	80	–64	0	100	0	58.5
58[f]	291.7	1	Shelf	25	–20	0	100	0	29.2
59[f]	1,572.7	2	Shelf	80	–64	0.2	99.8	0	29.2
60[f]	613.7	1	Shelf	25	–20	2.8	97.2	0	29.2
61[g]	631.6	1	Shelf	25	–20	0	100	0	29.2
62[f]	288.0	1	Shelf	25	–20	0	100	0	29.2
63	891.6	3	Oceanic	150	–120	26.1	73.9	0	7.3
64[a]	9.2	4	Oceanic	500	–400	0	100	0	29.2
65[a]	138.7	4	Oceanic	500	–400	1.6	98.4	0	7.3

[a]Flora and fauna protected area.
[b]San Lorenzo Archipelago National Park.
[c]Isla Tiburon.
[d]Isla Angel de la Guarda.
[e]San Jorge Island Reserve.
[f]Colorado River Delta Biosphere Reserve (buffer zone).
[g]Colorado River Delta Biosphere Reserve (nuclear zone).

Gerhardinger et al. 2009, Turvey et al. 2010). Despite the advantages of LEK data—being inexpensive to collect and applicable to a wide range of species—the imprecise nature of this anecdotal information hinders its use in a quantitative framework. Therefore, a flexible semiquantitative fuzzy logic framework is applied by Ainsworth (in press) to integrate LEK survey information collected in the PANGAS project with other information and generate time series of relative abundance. A brief summary is provided below.

Researchers from COBI and CEDO conducted LEK interviews with 81 fishers in the northern gulf region from April-June 2008 and September-February 2009. The fishers ranged in age from 20–89 years and on average had 28.5 years of fishing experience each. The interviews were in-depth and covered a wide range of topics from the status of the environment and fisheries activity to governance issues, socioeconomics, and quality of life. Among the many useful data that emerged was a ranking of the relative abundance of species groups from 1950 to 2008. Although there is much uncertainty in such anecdotal data (Brook and McLachlan 2005), the fishers' perceptions are our best sources of information for many of the data-poor species in the northern gulf.

Using a fuzzy logic approach, Ainsworth (in press) combined this LEK information with other data: results from simple stock assessment models built for that study, CPUE data derived from Mexican fisheries statistics (an indicator of relative abundance), and a measure of species vulnerability to fishing (Cheung et al. 2005). Together these sources yielded quantitative estimates of relative abundance that are used here to set biomass in the 1985 model and form time series trends from 1985 to 2008, useful for model testing. Biomass estimates for the 1985

Table 6. Method used to establish spatial distribution of functional groups.

Group	Method*	Group	Method*
Gulf coney	1	Oceanic sea turtles	2
Extranjero	3	Reef associated turtles	2
Leopard grouper	3	Sea birds	2
Gulf grouper	3	Benthic bacteria	5
Amarillo snapper	3	Scallops and penshells	4
Barred pargo	3	Penaeid shrimp	12
Groupers and snappers	3	Sea cucumbers	4
Drums and croakers	3	Sessile invertebrates	4
Grunts	3	Crabs and lobsters	4
Herbivorous fish	3	Herbivorous echinoderms	4
Large reef fish	3	Carnivorous macrobenthos	4
Small reef fish	3	Infaunal epifaunal meiobenthos	4
Small demersal fish	3	Bivalves	4
Pacific angel shark	3	Snails	4
Small migratory sharks	3	Adult blue crab	4
Large pelagic sharks	3	Juvenile blue crab	10
Guitarfish	3	Labile detritus	8
Skates, rays, sharks	3	Refractory detritus	8
Flatfish	3	Macroalgae	9
Mojarra	3	Pelagic bacteria	5
Scorpionfish	3	Large phytoplankton	5
Lantern fish and deep	3	Small phytoplankton	5
Totoaba	4	Adult blue shrimp	12
Large pelagics	3	Juvenile blue shrimp	12
Mackerel	3	Seagrass	11
Hake	5	Jellyfish	5
Small pelagics	1	Large zooplankton	5
Mysticeti	7	Squid	5
Odontocetae	2	Small zooplankton	5
Orca	2	Microphytobenthos	6
Vaquita	2	Carrion detritus	8
Pinnipeds	2		

*Method:

1. Habitat affinities from FishBase.
2. Habitat affinities set manually (mammals, birds, reptiles).
3. FishBase habitat affinities weighted at 10%, transect biomass allocation algorithm 90% (combination).
4. Transect biomass allocation algorithm only.
5. Uniform distribution.
6. Coastal polygons (not set with habitat affinities) assume 80 m or less.
7. Set using WWF occurrence distributions from interviews (assumed 50% abundance in Canal de Ballenas).
8. Detritus assumed proportional to total sum biomass in each polygon.
9. Set using WWF occurrence distributions from interviews.
10. As adult crabs.
11. Seagrass (as halophytes) from Glenn et al. 2006.
12. Assume same proportion as skates, rays, and sharks (occurs in muddy areas of northern gulf).

model derived from this method are presented in Table B-2 and time series information used in tuning the 1985 model is shown in Figure B-10.

Functional Group Descriptions

Gulf Coney (FBP)

This group includes the grouper gulf coney, aka baqueta (Serranidae). There is no biomass information available for this deepwater species in the Gulf of California, although the stocks are thought to be seriously depressed as a result of overfishing (Aburto-Oropeza et al. 2008a). We chose a conservative placeholder value of 5,000 mt for the entire northern gulf, or 86.5 kg • km^{-2} averaged over the study area. To put this amount into context, it represents about six times the biomass of our extranjero estimate, and about one-fifteenth of the gulf grouper biomass estimate. This biomass yields a reasonable fishing mortality for this group (0.094 yr^{-1}) with respect to the estimated catches in the 2008 model (471 mt).

This species occurs in the Gulf of California at depths greater than 45 m (Aburto-Oropeza et al. 2008a); this value agrees with previous studies (Heemstra 1995). However, the main concentration of biomass occurs as deep as 100 m.[15] The spatial distribution of biomass is based on habitat affinities from the FishBase ecology table. Diet of adult gulf coney was set using a simple averaging method to summarize gut contents from stomach samples because there was insufficient data available to use the statistical method outlined in Ainsworth et al. (2010) (gulf coney was in one sample from the stomach sampling program supporting the current model and three studies in FishBase). Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were adjusted to reflect a greater abundance of small-bodied prey.

Extranjero (FDB)

This group includes extranjero, aka spotted sand bass, and parrot sand bass (Serranidae). Like gulf coney, extranjero are known to occur in deep water (>100 m) in the Gulf of California (Aburto-Oropeza et al. 2008a). Reef transect studies conducted by PANGAS did not sample at sufficient depths to gain an accurate conception of this group's biomass. The only quantitative data available on extranjero biomass come from Nava-Romo (1994). We used his data on shrimp trawl bycatch to estimate the biomass of extranjero at 5.4 kg • km^{-2}, and subsequently increased that estimate by a factor of 20 to 0.11 t • km^{-2} (6,243 mt) to yield a reasonable fishing mortality (0.089 yr^{-1}) in view of recorded catches in the 2008 model (556 mt). Diet of adult extranjero was set using stomach samples analyzed by the maximum likelihood method (Ainsworth et al. 2010). Diet for extranjero was based on unidentified species in genus *Paralabrax* (21 samples, all from the Fish gut content analysis subsection above). Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

[15] See footnote 14.

Leopard Grouper (FDC)

This group includes the leopard grouper (Serranidae). Biomass was estimated using data from Thomson and Mesnick (1993), Thomson et al. (1996), NWFSC trawl surveys, ISPM transects, PANGAS transects, and Scripps transects, and interpolated using the biomass allocation algorithm. The biomass estimate was subsequently reduced to one-fifth during model tuning to 3,600 mt (0.062 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.103 yr^{-1}) with respect to the estimated catches in the 2008 model (371 mt). No quantitative feeding information could be located for this group, so we assumed a similar diet as gulf grouper, but the adult group was said to eat relatively less crab and more fish because of qualitative remarks made by Heemstra and Randall (1993).

Gulf Grouper (FDD)

This group includes the gulf grouper (Serranidae). Biomass was estimated using data from Thomson and Mesnick (1993), ISPM transects, ISPM transects (diversity study), and Scripps transects, and interpolated using the biomass allocation algorithm. The estimate was subsequently reduced to one-tenth during model tuning to 2,966 mt (0.051 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.063 yr^{-1}) with respect to the estimated catches in the 2008 model (186 mt). Diet of adult gulf grouper was set using a simple averaging method to summarize gut contents from stomach samples. The gulf grouper was represented in one sample from the gut content analysis (Fish gut content analysis subsection above) and three studies in FishBase. Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Amarillo Snapper (FDE)

This group consists of the amarillo snapper. Biomass was estimated using data from Thomson and Mesnick (1993), Thomson et al. (1996), ISPM transects, ISPM transects (diversity study), PANGAS transects, and Scripps transects and interpolated using the biomass allocation algorithm. The estimate is 3,480 mt (0.06 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.081 yr^{-1}) with respect to the estimated catches in the 2008 model (282 mt). No quantitative feeding information could be located for this species, so diet is based on qualitative remarks made by Allen (1985). Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Barred Pargo (FDF)

Barred pargo comprise this group. Biomass was estimated using data from Thomson and Mesnick (1993), Thomson et al. (1996), ISPM transects, and ISPM transects (diversity study) and interpolated using the biomass allocation algorithm. The estimate is 1,795 mt (0.031 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.138 yr^{-1}) with respect to the estimated catches in the 2008 model (247 mt). Diet of adult barred pargo was based on stomach samples from a single specimen. Because of the uncertainty, we included additional prey items that we considered likely, following the functional group groupers and snappers. Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Groupers and Snappers (FDM)

Groupers and snappers includes 29 groupers (Serranidae) and 6 snappers (Lutjanidae) not elsewhere included. Biomass was estimated using data from Nava-Romo (1994), Thomson and Mesnick (1993), Thomson et al. (1996), Gilligan (1980), NWFSC trawl surveys, ISPM transects, ISPM transects (diversity study), PANGAS transects, and Scripps transects, and interpolated using the biomass allocation algorithm. The estimate is 39,546 mt (0.684 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.081 yr^{-1}) with respect to the estimated catches in the 2008 model (3,206 mt). Generally, groupers spawn in spring and summer, while snappers spawn in summer and fall.[16] This is a potential source of error for this highly aggregated group (spring spawning date was used, see Figure 2 and Table A-7). Diet of adult groupers and snappers was set using a simple averaging method to summarize gut contents from stomach samples. Diet for groupers and snappers was based on mutton hamlet (*Alphestes afer*), goliath grouper (*Epinephelus itajara*), Colorado snapper (*Lutjanus colorado*), and spotted rose snapper (*Lutjanus guttatus*) (based on six samples from FishBase). Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Drums and Croakers (FDO)

Drums and croakers includes 29 drums and croakers (Sciaenidae). Due to a limited sampling area, we considered it likely that the biomass calculated for drums and croakers using methodology described in the Spatial Biomass Distributions subsection above was an underestimate. We therefore combined the biomass value for drums provided by Lozano (2006) with the estimate for croakers provided by Morales-Zárate et al. (2004) to yield 2.773 t • km^{-2}, and took this for biomass density. This biomass yields a reasonable fishing mortality for this group (0.171 yr^{-1}) with respect to the estimated catches in the 2008 model (27,373 mt). Diet of adult drums and croakers was set using stomach samples analyzed by the maximum likelihood method (Ainsworth et al. 2010). Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey. Diet for drums and croakers was based on white seabass, corvine spp., orangemouth corvina (*Cynoscion xanthulus*), Pacific drum (*Larimus pacificus*) and gulf croaker (40 samples, of which 55% were from the gut content study [Fish gut content analysis subsection above] and the remainder was from FishBase).

Grunts (FDP)

This group includes grunts (Haemulidae): silvergray grunt (*Anisotremus caesius*), sargo (*A. davidsonii*), blackbarred grunt (*A. dovii*), burrito grunt (*A. interruptus*), Panamic porkfish (*A. taeniatus*), armed grunt (*Conodon serrifer*), Cortez grunt (*Haemulon flaviguttatum*), spottail grunt (*H. maculicauda*), mojarra grunt (*H. scudderii*), graybar grunt (*H. sexfasciatum*), Latin grunt (*H. steindachneri*), wavyline grunt (*Microlepidotus inornatus*), humpback grunt (*Orthopristis chalceus*), bronzestriped grunt (*O. reddingi*), Panamic grunt (*Pomadasys*

[16] O. Aburto-Oropeza, Scripps Institution of Oceanography, Univ. California San Diego, La Jolla, CA. Pers. commun., September 2008.

panamensis), and salema (*Xenistius californiensis*). Biomass was estimated using data from Nava-Romo (1994), Thomson and Mesnick (1993), NWFSC trawl surveys, ISPM transects (diversity study), PANGAS transects, and Scripps transects and interpolated using the biomass allocation algorithm. The estimate was subsequently reduced to one-fifth to 2,795 mt (0.048 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.008 yr^{-1}) with respect to the estimated catches in the 2008 model (22 mt). Diet of adult grunts was based on FishBase data for Panamic grunt. Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Herbivorous Fish (FDS)

This group includes parrotfishes (Scaridae) and herbivorous species from other families. Herbivory was determined based on the "mainfood" and "herbivory2" fields of the FishBase ecology table. Parrotfishes, rudderfishes, and surgeonfishes were shown to be most responsible for grazing on algal communities in the Gulf of California, although the specific concentrations of these species vary widely between algal patches (Montgomery et al. 1980). Biomass was estimated using data from Thomson and Mesnick (1993), Thomson et al. (1996), ISPM transects, ISPM transects (diversity study) and Scripps transects, and interpolated using the biomass allocation algorithm. The estimate is 14,740 mt (0.255 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.169 yr^{-1}) with respect to the estimated catches in the 2008 model (2,484 mt). Diet of adult herbivorous fish was set using stomach samples analyzed by the maximum likelihood method (Ainsworth et al. 2010). Diet for herbivorous fish was based on opaleye, aka chopa verde (*Girella nigricans*), zebraperch, aka chopa bonita (*Hermosilla azurea*), striped mullet, white mullet (*Mugil curema*), and bluechin parrotfish (*Scarus ghobban*) (12 samples from FishBase). Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Large Reef Fish (FMM)

The large reef fish group includes 8 snake eels (Ophichthidae), 10 conger and garden eels (Congridae), 3 triggerfishes (Balistidae), 14 wrasses (Labridae), 8 cusk-eels (Ophidiidae), 1 false moray (Chlopsidae), 1 tripletail (Lobotidae), 1 roosterfish (Nematistiidae), 1 snipe eel (Nemichthyidae), 2 croakers (Sciaenidae), 1 oarfish (Regalecidae), 5 rockfishes (Sebastidae), 1 wreckfish (Polyprionidae), and 1 cutlassfish (Trichiuridae). Biomass was estimated using data from Nava-Romo (1994), Thomson and Mesnick (1993), Thomson et al. (1996), Gilligan (1980), ISPM transects, ISPM transects (diversity study), PANGAS transects, and Scripps transects and interpolated using the biomass allocation algorithm. The estimate is 57,051 mt (0.987 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.02 yr^{-1}) with respect to the estimated catches in the 2008 model (1,166 mt). Diet of adult large reef fish was set using stomach samples analyzed by the maximum likelihood method (Ainsworth et al. 2010). Diet for large reef fish was based on finescale triggerfish, California sheephead, yellow-brown wrasse (*Thalassoma lutescens*), surge wrasse (*T. purpureum*), and cutlassfish (*Trichiurus lepturus*) (37 samples, of which 18 samples were from the gut content study [Fish gut content analysis subsection above] and the remaining samples were from studies in FishBase). Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Small Reef Fish (FMN)

The small reef fish group includes 1 needlefish (Belonidae), 13 damselfishes (Pomacentridae), 8 flagblennies (Chaenopsidae), 2 filefishes (Monacanthidae), 1 frogfish (Antennariidae), 4 cardinalfishes (Apogonidae), 4 clingfishes (Gobiesocidae), 4 puffers (Tetraodontidae), 10 gobies (Gobiidae), 1 tilefishes (Malacanthidae), 2 batfishes (Ephippidae), 4 butterflyfishes (Chaetodontidae), 3 porcupinefishes (Diodontidae), 3 hawkfishes (Cirrhitidae), 3 pipefishes/seahorses (Syngnathidae), 12 moray eels (Muraenidae), 1 threefin blenny (Tripterygiidae), 4 combtooth blennies (Blenniidae), 1 cornetfish (Fistulariidae), 2 viviparous brotulas (Bythitidae), 2 bigeyes (Priacanthidae), 3 angelfishes (Pomacanthidae), 1 aholeholes (Kuhliidae), 2 sea chubs (Kyphosidae), 8 labrisomids (Labrisomidae), 2 boxfishes (Ostraciidae), 1 goatfish (Mullidae), 1 soldierfish (Holocentridae), 1 jawfish (Opistognathidae), 1 lizardfish (Synodontidae), and 1 moorish idol (Zanclidae).

Of these, the bullseye pufferfish, aka botete, is an important commercial fish in the northern gulf region (PANGAS Rapid Appraisal interviews, Cudney-Bueno unpubl. data). As a reef fish group, this group includes only the species of these families known to occur on hard bottoms. The preferred substrate was identified based on the habitat fields in the FishBase ecology table; these species are reported to occur in rocky, coral reef, and hard bottom substrates. Where information in the ecology table was insufficient, habitat was determined based on the DemersPelag field of the species table; species designated as “reef-associated” were allocated to this group.

Biomass was estimated using data from Nava-Romo (1994), Thomson and Mesnick (1993), Thomson et al. (1996), Gilligan (1980), NWFSC trawl surveys, ISPM transects, ISPM transects (diversity study), PANGAS transects, and Scripps transects and interpolated using the biomass allocation algorithm. The estimate is 152,407 mt (2.637 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.038 yr^{-1}) with respect to the estimated catches in the 2008 model (5,773 mt). Diet of adult small reef fish was set using stomach samples analyzed by the maximum likelihood method (Ainsworth et al. 2010). Diet for small reef fish was based on scrawled filefish (*Aluterus scriptus*), stripebelly puffer (*Arothron hispidus*), guineafowl puffer (*A. meleagris*), Pacific golden-eyed tilefish, ocean whitefish, Pacific spadefish (*Chaetodipterus zonatus*), balloonfish (*Diodon holocanthus*), porcupinefish (*D. hystrix*), reef cornetfish (*Fistularia commersonii*), forcepsfish (*Forcipiger flavissimus*), glasseye snapper (*Heteropriacanthus cruentatus*), spiny boxfish (*Lactoria diaphana*), spotted boxfish (*Ostracion meleagris*), and Moorish idol (*Zanclus cornutus*) (14 samples from the gut content study [Fish gut content analysis subsection above] and 19 samples from FishBase studies). Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Small Demersal Fish (FPL)

The small demersal fish group includes 1 bonefish (Albulidae), 5 moray eels (Muraenidae), 2 frogfishes (Antennariidae), 23 gobies (Gobiidae), 1 aulopus (Aulopidae), 2 threefin blennies (Tripterygiidae), 4 sea catfishes (Ariidae), 1 slickhead (Alepocephalidae), 2 tubeshoulders (Platytroctidae), 1 codlet (Bregmacerotidae), 1 grenadier (Macrouridae), 1 porgy (Sparidae), 2 pearlfishes (Carapidae), 1 viviparous brotula (Bythitidae), 1 tilefish

(Malacanthidae), 4 snooks (Centropomidae), 7 pikeblennies, tubeblennies, and flagblennies (Chaenopsidae), 1 porcupinefish (burrfishes) (Diodontidae), 16 labrisomids (Labrisomidae), 8 sand stargazers (Dactyloscopidae), 2 hagfishes (Myxinidae), 1 cornetfish (Fistulariidae), 3 sea chubs (Kyphosidae), 10 clingfishes and singleslits (Gobiesocidae), 3 combtooth blennies (Blenniidae), 1 stargazer (Uranoscopidae), 4 puffers (Tetraodontidae), 1 eelpout (Zoarcidae), 1 worm eel (Moringuidae), 3 greenlings (Hexagrammidae), 2 jawfishes (Opistognathidae), 3 snailfishes (Liparidae), 1 lanterneye fish (Anomalopidae), 4 needlefishes (Belonidae), 3 toadfishes (Batrachoididae), 1 soldierfish (Holocentridae), 2 lizardfishes (Synodontidae), and 1 surfperch (Embiotocidae).

These represent the same families as FMN (small reef fish), but species were sorted to include fish occurring only on soft substrate (sand and mud). The preferred substrate was determined based on the habitat fields in the FishBase ecology table; these species occur in soft and softbottom habitats. Where information in the ecology table was insufficient, habitat was determined based on the DemersPelag field of the species table; species designated as demersal, bathydemersal, pelagic, bathypelagic, and benthopelagic were allocated to this group. Biomass was estimated using data from Nava-Romo (1994), Thomson and Mesnick (1993), Thomson et al. (1996), Gilligan (1980), NWSFC trawl surveys, ISPM transects, ISPM transects (diversity study), PANGAS transects, and Scripps transects, and interpolated using the biomass allocation algorithm. The estimate is 302,413 mt (5.232 t • km^{-2}). This biomass yields a small fishing mortality (<0.001 yr^{-1}) with respect to the estimated catches in the 2008 model (106 mt). Diet of adult small demersal fish was set using stomach samples analyzed by the maximum likelihood method (Ainsworth et al. 2010). Diet for small demersal fish was based on bonefish (*Albula vulpes*), Pacific porgy, black snook (*Centropomus nigrescens*), yellowfin snook (*C. robalito*), California moray (*Gymnothorax mordax*), sea catfish (*Sciades platypogon*), and puffers (*Sphoeroides* spp.) (17 samples from the gut content study and 7 samples from FishBase studies). Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Pacific Angel Shark (FPS)

This group includes the Pacific angel shark (*Squatina californica*) (Squatinidae). These fish are nocturnal (Fouts and Nelson 1999), which we capture in the model. Biomass was estimated using data from Nava-Romo (1994) and interpolated using the biomass allocation algorithm. The estimate was subsequently increased by a factor of 10 during model tuning to 3,693 mt (0.064 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.118 yr^{-1}) with respect to the estimated catches in the 2008 model (434 mt). We used a fixed recruitment relationship in Atlantis in which each female was assumed to birth 0.44 viable pups per year. This implies a high rate of juvenile mortality, since Holts (1988) suggested six pups are birthed per year, although a more conservative value may be appropriate (DeCraene and Fink 2004). Diet of adult Pacific angel shark was set using gut contents from a single specimen; we therefore included other likely prey items ad hoc. Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Small Migratory Sharks (FPO)

This group includes smoothhounds (*Mustelus* spp.) (Triakidae): sharptooth smoothhound (*Mustelus dorsalis*), brown smoothhound (*M. henlei*), sicklefin smoothhound (*M. lunulatus*), and gray smoothhound (*M. californicus*). We assumed that small migratory sharks enter the model domain as of the March 1 migration date, the migration is complete within 30 days, migration out of the study area begins on June 1, and 50% of individuals leave from each polygon. A biomass of 2.99 t • km^{-2} was assumed based on Lozano (2006). This biomass yields a reasonable fishing mortality for this group (0.133 yr^{-1}) with respect to the estimated catches in the 2008 model (22,999 mt). Fixed recruitment was used for this group in which females were assumed to produce 0.65 viable pups per year. This value produced reasonable population growth rates in the absence of fishing mortality. Diet was based on the maximum likelihood estimates made in Ainsworth et al. (2010) using stomach samples collected for this analysis (1 sample) and FishBase data (9 studies). These data represent diets of gray smoothhound, brown smoothhound, sicklefin smoothhound, and smoothhound species (unidentified). We also considered an independent analysis of elasmobranch diets based on gray smoothhound, brown smoothhound, and sicklefin smoothhound by (Cortés 1999).

Large Pelagic Sharks (FVB)

This group includes all elasmobranchs of superorder Selachimorpha: bigeye thresher shark (*Alopias superciliosus*), thresher shark (*A. vulpinus*), pelagic thresher shark (*A. pelagicus*), blacktip shark (*Carcharhinus limbatus*), dusky shark (*C. obscurus*), smalltail shark (*C. porosus*), bull shark (*C. leucas*), white shark (*Carcharodon carcharias*), nurse shark (*Ginglymostoma cirratum*), Pacific sharpnose shark (*Rhizoprionodon longurio*), smooth hammerhead shark (*Sphyrna zygaena*), scalloped hammerhead shark (*S. lewini*), great hammerhead shark (*S. mokarran*), and shortfin mako shark (*Isurus oxyrinchus*). We assumed that large pelagic sharks enter the model domain as of the migration date, March 1, and that the migration is complete within 30 days. We assumed migration out of the study area begins on June 1 and that 25% of individuals leave from each polygon. Biomass density was set as 0.79 • km^{-2} based on Morales-Zarate et al. (2004). This biomass yields a reasonable fishing mortality for this group (0.007 yr^{-1}) with respect to the estimated catches in the 2008 model (304 mt). We used a fixed recruitment relationship in Atlantis in which each female was assumed to birth 0.15 viable pups per year. This value produced a reasonable population growth rate in the absence of fishing mortality. Diet for this group was based on bull shark, blacktip shark, dusky shark, smalltail shark, Pacific sharpnose shark, Caribbean sharpnose shark (*Rhizoprionodon porosus*), scalloped hammerhead shark, great hammerhead shark, smooth hammerhead shark, bigeye thresher shark, thresher shark, white shark, shortfin mako shark, and nurse shark (Cortés 1999).

Guitarfish (FVD)

This group includes guitarfishes (Rhinobatidae): thornback guitarfish (*Platyrhinoidis triseriata*), banded guitarfish (*Zapteryx exasperata*), whitesnout guitarfish (*Rhinobatos leucorhynchus*), speckled guitarfish (*R. glaucostigma*), and shovelnose guitarfish (*R. productus*). Biomass density was set as 1.104 t • km^{-2} based on Morales-Zarate et al. (2004). This biomass yields a reasonable fishing mortality for this group (0.096 yr^{-1}) with respect to the estimated catches in the 2008 model (6,136 mt). We used a fixed recruitment relationship for this group in which the female was assumed to produce an average of 1.3 viable progeny per year. Therefore we assumed a juvenile mortality rate of about 85% based on fecundity of the common guitarfish (*R. rhinobatos*) (Abdel-Aziz et al. 1993). Adult guitarfish diet was set using a simple averaging method to summarize gut contents from stomach samples. One species (shovelnose guitarfish) was represented by three studies in FishBase. Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Skates, Rays, and Sharks (FVO)

The northern Gulf of California contains 58 species of Chondrichthyes (sharks, rays, and chimaeras) (Brusca et al. 2005). The skates, rays, and sharks group includes spotted eagle ray (*Aetobatus narinari*), longnose cat shark (*Apristurus kampae*), swell shark (*Cephaloscyllium ventriosum*), diamond stingray, whiptail stingray (*Dasyatis brevis*), bullseye electric ray (*Diplobatis ommata*), longsnout butterfly ray (*Gymnura crebripunctata*), California butterfly ray (*G. marmorata*), horn shark (*Heterodontus francisci*), Mexican horn shark (*H. mexicanus*), spotted ratfish (*Hydrolagus colliei*), smoothtail mobula (*Mobula thurstoni*), bat ray (*Myliobatis californica*), longnose eagle ray (*M. longirostris*), giant electric ray (*Narcine entemedor*), equatorial skate (*Raja equatorialis*), golden cownose ray (*Rhinoptera steindachneri*), leopard shark (*Triakis semifasciata*), reef stingray (*Urobatis concentricus*), round ray (*U. halleri*), Cortez round stingray (*U. maculatus*), blotched stingray (*Urotrygon chilensis*) and thorny stingray (*U. rogersi*).

Important commercial members are butterfly ray and diamond stingray. Biomass was estimated using data from Nava-Romo (1994), NWFSC trawl surveys, ISPM transects, ISPM transects (diversity study), PANGAS transects, and Scripps transects and interpolated using the biomass allocation algorithm. The estimate is 62,321 mt (1.078 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.155 yr^{-1}) with respect to the estimated catches in the 2008 model (9,673 mt). We used a fixed recruitment relationship in Atlantis in which each female was assumed to birth 0.3 viable pups per year. This value produced a reasonable population growth rate in the absence of fishing mortality. Diet was based on two sources, the maximum likelihood estimates (Ainsworth et al. 2010) using 5 stomach samples collected in the gut content analysis and 19 FishBase studies covering spotted eagle ray, diamond stingray, horn shark, bat ray, California skate (*Raja inornata*), leopard shark, and round ray, and an independent analysis of elasmobranch diets based on shovelnose guitarfish, giant electric ray, diamond stingray, and California butterfly ray (Bizzarro 2005).

Flatfish (FVS)

The flatfish group includes 3 American soles (Achiridae), 13 large-tooth flounders (Paralichthyidae), 3 lefteye flounders (Bothidae), 2 righteye flounders (Pleuronectidae) and 12 tonguefishes (Cynoglossidae). Biomass density was set based on Morales-Zarate et al. (2004), but subsequently reduced during model tuning to one-fifth of that amount to 38,690 mt (0.669 t • km^{-2}). This biomass yields a reasonable fishing mortality for this group (0.087 yr^{-1}) with respect to the estimated catches in the 2008 model (3,360 mt). Diet of adult flatfish was set using stomach samples analyzed by the maximum likelihood method (Ainsworth et al. 2010). Diet for flatfish was based on threespot sand flounder (*Ancylopsetta dendritica*), flounders and halibut (*Paralichthys spp.*), and Pleuronectidae (8 samples from the gut content study and 1 sample from

FishBase). Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Mojarra (FVT)

This group includes mojarras (Gerreidae): golden mojarra (*Diapterus aureolus*), Peruvian mojarra (*D. peruvianus*), Pacific flagfin mojarra (*Eucinostomus currani*), darkspot mojarra (*E. entomelas*), black axillary mojarra (*Eugerres axillaris*), and yellowfin mojarra (*Gerres cinereus*). We adopted as a placeholder a previous biomass estimate from the EwE model of Morales-Zárate et al. (2004); however, we reduced their amount to one half during model tuning resulting in 4.13 t • km^{-2}. This biomass yields a reasonable fishing mortality for this group (0.057 yr^{-1}) with respect to the estimated catches in the 2008 model (1,369 mt). Adult mojarra diet was set using a simple averaging method to summarize gut contents from stomach samples. Three species (golden mojarra, Peruvian mojarra, and yellowfin mojarra) are represented by four samples. Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Scorpionfish (FVV)

This group includes scorpionfishes (Scorpaenidae) and sea robins (Triglidae): chevron searobin (*Bellator loxias*), splitnose searobin (*B. xenisma*), speckled scorpionfish (*Pontinus sierra*), whitesnout searobin (*Prionotus albirostris*), twobeak searobin (*P. birostratus*), rough searobin (*P. ruscarius*), lumptail searobin (*P. stephanophrys*), California scorpionfish (*Scorpaena guttata*), player scorpionfish (*S. histrio*), stone scorpionfish (*S. mystes*), spotted scorpionfish (*S. plumieri*), reddish scorpionfish (*S. russula*), Sonora scorpionfish (*S. sonorae*), and rainbow scorpionfish (*Scorpaenodes xyris*). Biomass was estimated using data from Nava-Romo (1994) and NWFSC trawl surveys and interpolated using the biomass allocation algorithm. The estimate is 8,805 mt (0.152 t • km^{-2}). This biomass yields a small fishing mortality for this group (<0.001 yr^{-1}) with respect to the estimated catches in the 2008 model (3 mt). Diet of adult scorpionfish was set using a simple averaging method to summarize gut contents from stomach samples. Two species (lumptail searobin and spotted scorpionfish) were represented in seven samples. Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Lanternfish and Deep (SHB)

This group includes lanternfishes (Myctophidae), barbeled dragonfishes (Stomiidae) and batfish (Ogcocephalidae): scaleless dragonfish (*Bathophilus filifer*), lamp fish (*Benthosema panamense*), Pacific viperfish (*Chauliodus macouni*), batfish (no common name, *Dibranchus hystrix*,) batfish (no common name, *D. spinosus*), slimtail lampfish (*Lampanyctus parvicauda*), black-belly dragonfish (*Stomias atriventer*), Mexican lampfish (*Triphoturus mexicanus*), and rounded batfish (*Zalieutes elater*). Biomass was estimated from Nava-Romo (1994) and interpolated using the biomass allocation algorithm. The estimate is 109,323 mt (1.891 t • km^{-2}). This biomass yields an appropriately small fishing mortality for this group (0.002 yr^{-1}) with respect to the estimated catches in the 2008 model (191 mt). Diet of adult lanternfish and deep was set using a simple averaging method to summarize gut contents from stomach samples. Fanged viperfish was represented in two studies from FishBase. Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey. Biomass for this group was based on Lozano (2006). His value, 1.891 t • km^{-2}, is intermediate between Morales-Zárate et al. (2004) (2.089 t • km^{-2}) and Arreguin-Sánchez et al. (2002) (0.863 t • km^{-2}).

Totoaba (SHC)

Only totoaba are included in this group. This sciaenid occurs only in the Gulf of California, from the mouth of the Colorado River to Rio Fuerte, Sinaloa, on the mainland side and to Bahia Concepcion on the peninsular side; greatest concentrations occur in the extreme north near Puerto Peñasco and El Golfo de Santa Clara (Sonora) and San Felipe (Baja California) (Arvizu and Chavez 1970). A biomass estimate was made based on Nava-Romo (1994), and interpolated using the biomass allocation algorithm (10.3 mt or 0.179 kg • km^{-2}), but this amount is far smaller than the values used by Morales-Zarate et al. (2004), 0.066 t • km^{-2}, or Lozano (2006), 0.016 t • km^{-2}. We therefore adopted the value of Lozano (2006), which corresponds to 919.1 mt for the northern gulf. Diet for these animals was based on the review by Cisneros-Mata et al. (1995). They cite four other articles and provide a qualitative description of prey items for both juvenile and adult totoaba. The von Bertalanffy growth parameters were available from Cisneros-Mata et al. (1995) as $k = 0.152$, $L_\infty = 169.9$ cm, and $t_o = -0.61$. Age at first reproduction was estimated to be 6 years for males and 7 years for females; we used an average value of 6.5 (Cisneros-Mata et al. 1995). Length-weight parameters were taken from Almeida-Paz et al. (1992) as cited by Lercari and Chávez (2007) ($a = 3.5 \cdot 10^{-5}$, $b = 2.59$).

The totoaba fishery played a pivotal historical role in the development of northern gulf towns, fishing infrastructure, and economy (Berdegue 1955, Flanagan and Hendrickson 1976). Heavy exploitation from the 1930s to the 1970s resulted in serious population depletion, and much of the catch was discarded in early years in the baled “buche” fishery (gas bladder) for export to China (Chute 1928). A sport fishery began in the 1920s, but had already subsided by the 1940s (Flanagan and Hendrickson 1976). The commercial fishery had also begun to decline by the 1940s, although this may have reflected the increasing price of shrimp and subsequent reorganization of fishing effort (Berdegue 1955). Nevertheless, after steady declines, the fishery was finally banned in 1975 and in 1976 this species had the unfortunate distinction of being the first marine fish to be added to the Convention on International Trade in Endangered Species (CITES) list of endangered species. In 1979 it was added to the U.S. Endangered Species List (Hastings and Findley 2007).

Time series estimates of catch for these fish vary between sources. For the main fishing period between 1929 and 1966, Ramírez (1967) estimated an annual mean of 686 mt originating from the Gulf of California, while Arvizu and Chavez (1970) estimated a higher mean for the same period, 956 mt. These authors agree that peak catches occurred in 1942, while Berdegue (1955) recorded that it occurred in 1946. The time series used for tuning the present model was constructed based on these three sources; we used their average values and assumed that 99% of the totoaba catch originates from the northern gulf study area based on ratios presented in Ramírez (1967). Continued removal of juvenile totoaba by shrimp vessels, especially during the fish’s ontogenetic migration, and continued poaching of adults, has kept fishing mortality high since the fishing ban (Flanagan and Hendrickson 1976, Cisneros-Mata et al. 1995).

For 1990 Z was estimated by Cisneros-Mata et al. (1995) as 0.185 yr^{-1} based on the catch-curve method of Ricker (1975), while (Pedrín-Osuna et al. 2001) estimated 0.695 yr^{-1} for the same period, the majority of which was from fishing. However, incidental fishing mortality, largely from the shrimp trawl fishery, has probably declined since 1993 following strict harvest restrictions in the northern gulf (Cisneros-Mata et al. 1995). We therefore assumed that fishing mortality constitutes half the total mortality, and adopted the value of Cisneros-Mata et al. (1995) to represent 2008, 0.093 yr^{-1}. Given the biomass estimated used here, this corresponds to a current annual catch of 85.5 mt.

Totoaba populations undergo annual migrations, retreating from warm waters in the coastal areas of the northern gulf during the summer months and returning around October. The greatest abundance of adult totoaba in the study area therefore occurs between January and March (Arvizu and Chavez 1970). The species shows an ontogenetic migration pattern, with prerecruits (<1 year old) and juveniles (1 and 2 year olds) occupying the shallow waters of the northern gulf and Colorado River delta (Cisneros-Mata et al. 1997). This is reflected in seasonal migration parameters.

Large Pelagics (SHD)

This group includes those large pelagics not elsewhere included: 5 tunas and bonitos (Scombridae), 18 jacks and pompanos (Carangidae), 1 dolphinfish (Coryphaenidae), 1 tenpounder (Elopidae), 1 opah (Lampridae), 2 molas (Molidae), 1 salmonid (Salmonidae), 2 butterfishes (Stromateidae), 1 morid cod (Moridae), 1 remora (Echeneidae), 2 barracudas (Sphyraenidae), and swordfish (*Xiphias gladius*). Biomass was estimated using data from NWFSC trawl surveys, ISPM transects, ISPM transects (diversity study), and Scripps transects and interpolated using the biomass allocation algorithm. The estimate is 25,761 mt or 0.446 $t \cdot km^{-2}$.

Catches from the Anuario Estadistico were high for Baja California and Sonora combined, but presumably a large portion of the catch originates from the Pacific and the lower gulf; we therefore assumed that 20% of the value was relevant for our area yielding a catch estimate of 2,460 mt or 0.043 $t \cdot km^{-2}$ ($F = 0.095\ yr^{-1}$). Diet of adult large pelagic fish was set using stomach samples analyzed by the maximum likelihood method (Ainsworth et al. 2010); the resulting data was then combined with additional gut content data using a simple averaging approach to account for other species not considered by the maximum likelihood analysis. Diet for large pelagics was based on threadfin jack (*Carangoides otrynter*), bigeye trevally (*Caranx sexfasciatus*), Pacific bumper (*Chloroscombrus orqueta*), dolphinfish (*Coryphaena hippurus*), skipjack tuna (*Katsuwonus pelamis*), longjaw leatherjack (*Oligoplites altus*), Chinook salmon (*Oncorhynchus tshawytscha*), remora (*Remora remora*), whale shark (*Rhincodon typus*), Pacific bonito (*Sarda chiliensis chiliensis*), yellowtail jack (*Seriola lalandi*), Mexican barracuda (*Sphyraena ensis*), and swordfish (based on 50 samples from FishBase). Diet for this group also considers sailfish from Rosas-Alayola et al. (2002). Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Mackerel (SHP)

This group includes mackerels (Scomberomorus spp.): snake mackerel (*Gempylus serpens*), Pacific chub mackerel (*Scomber japonicus*), Gulf sierra (*Scomberomorus concolor*), Pacific sierra (*S. sierra*), and jack mackerel (*Trachurus symmetricus*). A biomass estimate was made based on NWFSC transects and interpolated using the biomass allocation algorithm. However, as the estimate pertains to juveniles found near shore, it was arbitrarily increased by a factor of 100 to 0.53 t • km^{-2} to represent the entire population. This amount is close to the value used by Morales-Zarate et al. (2004), 0.49 t • km^{-2}. No other supporting data could be found for the northern gulf. As with the previous group large pelagics, available catch data from the Anuario Estadistico suggested a high catch value, but some of that catch may have originated from the Pacific and lower gulf. We therefore assumed that 20% was relevant to our study area, yielding a catch estimate of 2,314 mt or 0.040 t • km^{-2} (F = 0.076 yr^{-1}). Diet of adult mackerel was set using stomach samples analyzed by the maximum likelihood method (Ainsworth et al. 2010). Three species (Pacific sierra, Pacific chub mackerel, and jack mackerel) are represented by 20 samples, of which 13 samples were from the gut content analysis and the rest were from studies in FishBase. Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Hake (SHR)

This group includes hake (Merlucciidae): Cortez hake (*Merluccius hernandezi*) and Panama hake (*M. angustimanus*). No suitable biomass value was available for this group, so we used the biomass value of Morales-Zárate et al. (2004), who relied on Nelson et al. (1980). Their amount equates to 0.490 t • km^{-2} when averaged over the whole study area, or about 28,322 mt of standing stock biomass. Anuario Estadistico catch estimates suggested 378 mt or 0.007 t • km^{-2} caught at present (F = 0.013 yr^{-1}). This low level of fishing mortality suggests that there should be little depletion in this group, at least in recent years, a finding supported by Ainsworth (in press). No feeding information could be located for these species, so diet was based on Pacific hake (Livingston and Alton 1982) with prey items translated into equivalent Atlantis functional groups.

Small Pelagics (SSK)

Small pelagics includes 11 anchovies (Engraulidae), 1 argentine (Argentinidae), 6 silversides (Atherinopsidae), 1 deep-sea smelt (Bathylagidae), 2 flying fishes (Exocoetidae) and 6 herrings and pilchards (Clupeidae). Few reliable studies exist on the biomass of small pelagics in the northern gulf, so we opted to use a value assembled from a previous ecosystem study. The biomass value for small pelagics used by Morales-Zárate et al. (2004) was 0.243 t • km^{-2}, which equates to 14,045 mt for the northern gulf study area. This small biomass was incommensurate with our catch records, which indicated that more than 470,000 mt were caught in 2007 from the entire gulf (Diario Oficial de la Federación 2006a). Although only a fraction of that recorded catch would have originated from the northern gulf study area, we nevertheless substituted the larger biomass value estimated by Lozano (2006), which was 3.122 t • km^{-2} (180,450 mt). The value is uncertain, as he used EwE to estimate it; however, he also cited Pérez-Mellado (1980) for supporting evidence.

Data presented in Casas-Valdez and Ponce-Díaz (1996) corroborates at least that rough magnitude of small pelagic biomass. Those authors cite the value provided by Rodríguez Sánchez et al. (1996), which is 200,000 mt for Pacific sardine (*Sardinops sagax*) in all Baja California Sur. It is likely that most of the small pelagic catch (which is dominated by sardines) occurs from the mid to lower gulf (Lluch-Belda and Magallón-Barajas 1986), so we reduced the catch estimate in the model to 20% of the values in Diario Official de la Federación (2006a), yielding a catch estimate for our region of 47,289 mt, or 0.818 t • km^{-2} ($F = 0.262\ yr^{-1}$). Adult small pelagic fish diet was set using a simple averaging method to summarize gut contents from stomach samples. Pacific sardine was represented by six studies in FishBase. Diet of juveniles was assumed to consist of similar prey as adults, but proportions of some items were skewed toward small-bodied prey.

Mysticeti (WHB)

Present in the Gulf of California are 23 to 31 of the 86 recognized cetacean species in the world (Brusca et al. 2005, Urbán-Ramírez et al. 2005, Guerrero-Ruíz et al. 2006). Mysticeti members inhabiting this area include fin whale (*Balaenoptera physalus*), gray whale (*Eschrichtius robustus*), humpback whale (*Megaptera novaeangliae*), minke whale (*B. acutorostrata*), Bryde's whale (*B. edeni*), blue whale (*B. musculus*) and North Pacific right whale (*Eubalaena japonica*). This group also includes the whale shark. Although they are elasmobranchs, they were placed into this group instead of the large pelagic shark group due to their planktonic feeding habits, which more closely resemble those of baleen whales than carnivorous large sharks that attack large prey (Stevens 2006). Whale sharks are lecithotrophic livebearers (Joung et al. 1996) and highly fecund, producing up to 300 embryos per litter, by far the largest for any species of shark (Stevens 2006). Whale sharks therefore are more fecund than other members of the mysticeti group; this is a potential source of error. Whale sharks occupy the northern Gulf of California between May and December (Cárdenas-Torres et al. 2007). We used a fixed recruitment relationship in Atlantis in which each female was assumed to birth 0.04 viable offspring per year.

The National Marine Fisheries Service (NMFS) recognizes fin whale populations in the northeastern Pacific Ocean and the Gulf of California as belonging to the California-Oregon-Washington stock. The Gulf of California is on the southern edge of their distribution (Angliss and Lodge 2002). The population of fin whales in the area was estimated to be 1,385 individuals in 1993 (Mangels and Gerrodette 1994), between 400 and 800 in 1996 (Gerrodette and Palacios 1996), and 600 in 2006 (Guerrero-Ruíz et al. 2006) but possibly more (Urbán-Ramírez et al. 2005). The population is likely resident (Silber et al. 1994), occupying the central gulf and making feeding trips into the northern gulf (Urbán-Ramírez 2002). Assuming 600 (the most recent census) and multiplying by mean body weights in Trites and Pauly (1998) provides a biomass estimate of 33,354 mt.

Gray whales occurring in the Gulf of California are members of the California-Chukchi stock, one of two in the North Pacific (Weller et al. 1999). They migrate into the study area during winter for rearing, but feed during the summer in the cold waters of the Bering Sea, Gulf of Alaska, and Chukchi Sea (Gendron and Urbán-Ramírez 1993, Urbán-Ramírez et al. 2005). About 500 individuals occupy the Gulf of California according to median values reported in

Urbán-Ramírez et al. (2005), which equates to 7,686 mt assuming mean body weights reported in Trites and Pauly (1998).

Humpback whales concentrate in the central and northeastern Pacific during the winter breeding season, including the Gulf of California (Gendron and Urbán-Ramírez 1993). The Pacific population suffered heavy losses from hunting; at its lowest level in the late 1960s there were only 1,200 individuals, down from a virgin population size of 125,000 (Guerrero-Ruíz et al. 2006). Guerrero-Ruíz et al. (2006) estimate 2,000 individuals now winter in the Gulf of California, which equates to 60,816 mt using mean body weights in Trites and Pauly (1998); this is slightly larger than the median estimate of Urbán-Ramírez et al. (2005) of 1,813 animals. Humpbacks are present only in the winter and spring (Urbán-Ramírez et al. 2005).

Minke whales in the North Pacific number between 17,000 and 28,000, but the fraction occupying Mexican waters is unknown (Guerrero-Ruíz et al. 2006). Urbán-Ramírez et al. (2005) provide a rough estimate of 100 animals, which suggests 657 mt assuming body weights in Trites and Pauly (1998). They apparently occupy the area year-round (Urbán-Ramírez et al. 2005).

Gerrodette and Palacios (1996) estimate that 952 Bryde’s whales are in the Gulf of California. This estimate is slightly larger than the one by Urbán-Ramírez et al. (2005). Mangels and Gerrodette (1994) record that 14.3% of individuals sighted in the gulf were within the present study area, so we reduce the estimate to reflect this and multiply by body weights to suggest 2,197 mt. It is possible that two separate populations of Bryde’s whales use the area: one resident population and one transient (Dizon et al. 1995, Guerrero-Ruíz et al. 2006). As we do not have a reliable estimate for the relative size of these populations, we assumed a 50:50 split.

Blue whales number between 362 and 576 in the Gulf of California (Gendron and Gerrodette 2004, Guerrero-Ruíz et al. 2006). They are known to winter in the area for feeding, reproduction, and rearing (Gendron 2002, Urbán-Ramírez et al. 2005, Guerrero-Ruíz et al. 2006). Assuming the median value and mean body weights in Trites and Pauly (1998) gives a biomass estimate of 48,182 mt.

There are possibly 225 North Pacific right whales in the gulf, equal to about 5,261 mt assuming mean individual weights (Trites and Pauly 1998). Sei whales (*Balaenoptera borealis*) may also seasonally occupy the Gulf in small numbers, perhaps 100 animals (Urbán-Ramírez et al. 2005); this equates to 1,681 mt. Summing these values suggests a winter biomass in the Gulf of California for mysticeti of 159,834 mt. Table 7 summarizes the information.

We assumed that the population is distributed mostly in the south of the model area near the Canal de Ballenas, a feeding area for migratory cetaceans (Tershy et al. 1991). We assumed that 71.5% of the population begins the simulation outside of the model domain, based on the numbers of individuals in the eight principle species outlined above and their winter-to-summer occupation schedules. We assumed mysticeti enter the model domain as of the migration date, September 1, and that the migration is complete within 40 days. Migration out of the study area begins on March 1 and lasts 40 days. Diet for these animals was set similarly to Lozano’s (2006) baleen whales functional group, with the diet consisting of more than 90% zooplankton, of which we assumed 70% is large-bodied plankters and 30% is small, and phytoplankton, which we

Table 7. Seasonal mysticeti biomass in the Gulf of California.

Species	Biomass (mt)	
	Winter/spring	Summer/fall
Fin whale	33,354	33,354
Gray whale	7,686	—
Humpback whale	60,816	—
Minke whale	657	657
Bryde's whale	2,197	7,684
Blue whale	48,182	—
North Pacific right whale	5,261	—
Sei whale	1,681	—
Totals	159,834	41,695

assumed consists equally of large and small body size groups; these values were changed somewhat during tuning. We also included a small amount of small pelagic fish in their diet after Perrin et al. (2002). Juvenile mysticeti were assumed to eat the same items in similar proportion as adults.

Odontocetae (WHT)

There are 31 species of whales and dolphins recorded in the Gulf of California. The following are dominant in the north end: common dolphins (*Delphinus delphis*), long-beaked common dolphins (*D. capensis*), bottlenose dolphins (*Tursiops truncatus*), Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), Baird's beaked whale (*Berardius bairdii*), Risso's dolphins (*Grampus griseus*) (Jaquet and Gendron 2002, Urbán-Ramírez et al. 2005, Lluch-Cota et al. 2007). Also included in this group are sperm whales (*Physeter macrocephalus*), short fin pilot whales (*Globicephala macrorhynchus*), false killer whales (*Pseudorca crassidens*), and Cuvier's beaked whale (*Ziphius cavirostris*). The pygmy beaked whale (*Mesoplodon peruvianus*) and the pygmy sperm whale (*Kogia breviceps*) may also be present in the northern Gulf of California in small numbers (Guerrero-Ruíz et al. 2006). Fixed recruitment was used for this group; females were assumed to produce 0.09 viable offspring per year surviving to adulthood.

The most recent estimates suggest that there are 14,239 common dolphins and 1,416 bottlenose dolphins inhabiting the northern gulf (Silber et al. 1994), equivalent to 1,141 and 265.5 mt of biomass, respectively, using the mean body weights of Trites and Pauly (1998). The populations of both species could potentially be much larger (Urbán-Ramírez et al. 2005). Common dolphins are thought to undergo annual migrations into the gulf, while bottlenose dolphins seem to be resident (Silber et al. 1994). Both species occur most often in the southern gulf (Mangels and Gerrodette 1994). For common dolphins, we assumed 50% of the population remains in the gulf during the summer months. Gerrodette and Palacios (1996) estimated there were 69,456 long-beaked common dolphins present in the gulf in 1993. Only 88% of sightings were in the study area (Mangels and Gerrodette 1994), so we reduced this value by 12% and assumed similar body weight to the common dolphin, which suggests 4,899 mt. There may be 100 Baird's beaked whales present in the summer only and 250 Pacific white-sided dolphins present in the winter and spring (Urbán-Ramírez et al. 2005). This represents about 314 and 20 mt, respectively (Trites and Pauly 1998).

A report estimated 567 sperm whales within the Gulf of California (Gerrodette and Palacios 1996); the actual number may be higher (Jaquet and Gendron 2002, Guerrero-Ruíz et al. 2006) or lower (Mangels and Gerrodette 1994, Urbán-Ramírez et al. 2005). These animals are semiresident (Guerrero-Ruíz et al. 2006) in the gulf; we assumed that 50% depart the area in the summer. Although sperm whales typically inhabit waters deeper than 1,000 m, they are regularly found at shallower depths in the Gulf of California (Jaquet and Gendron 2002). At mean body weights reported in Trites and Pauly (1998), this equates to 11,055 mt.

An estimated 13,208 Cuvier beaked whales occurred in the gulf as of 1993 (Gerrodette and Palacios 1996), which we assumed is representative of today. This equates to 10,943 mt, assuming average weights from the above source. There is no clear seasonal pattern in reported strandings of Cuvier beaked whales in the northeast Pacific (Heyning 1989), so we assumed there is no strong seasonal migration in or out of the gulf. There are between 1,500 and 3,954 short fin pilot whales in the gulf (Mangels and Gerrodette 1994, Vázquez 1997, Urbán-Ramírez et al. 2005, Guerrero-Ruíz et al. 2006). The median value equates to 1,753 mt, when adjusted for mean body weight in Trites and Pauly (1998). This species is possibly resident in the area, since reports of strandings come year-round (Guerrero-Ruíz et al. 2006).

Pygmy beaked whales may occupy the gulf year-round. We have no population estimate, so we assumed a small population equal to half the number of short fin pilot whales (the least abundant odontocetae). Converting this to biomass using average body weights in Trites and Pauly (1998) suggests 252 mt. We assumed that all odontocetae species are resident unless otherwise noted. Seasonal biomass data for this functional group is summarized in Table 8.

We assumed that odontocetae enter the model domain as of the migration date, September 1, and that the migration is complete within 40 days. We assumed migration out of the study area begins on March 1 and lasts 40 days. Diet for toothed whales was based on Perrin et al. (2002) and consists mainly of squid and fish; we added a small amount of pelagic

Table 8. Seasonal odontocetae biomass in the Gulf of California.

	Biomass (mt)	
Species	**Winter**	**Summer**
Common dolphin	1,141	571
Long-beaked common dolphin	4,899	4,899
Bottlenose dolphin	266	266
Baird's beaked whale	—	314
Pacific white-sided dolphin	20	—
Sperm whale	11,055	5,528
Cuvier beaked whale	10,943	10,943
Short fin pilot whale	1,753	1,753
Pygmy beaked whale	252	252
Totals	30,329	24,526

invertebrates after Lozano (2006). Diet also included some benthic invertebrates, representing beaked whales that forage in deep waters (Jefferson et al. 1993); diet parameters were changed somewhat during tuning. We assumed that juvenile odontocetae eat similar items as the adults, but we increased the relative proportion of small bodied animals for pelagic and reef fish.

Orca (WHS)

Orcas, also known as killer whales, are resident in the Gulf of California (Silber et al. 1994, Guerrero-Ruíz et al. 2006). There are between 100 and 500 animals, but the number could potentially be lower (Silber et al. 1994). Mangels and Gerrodette (1994) agreed with this estimate. The median value, 300, equates to about 5,583 mt of biomass (0.097 t • km^{-2}), considering the mean body weights reported in Trites and Pauly (1998). We used a fixed recruitment relationship in Atlantis in which each female was assumed to birth 0.041 viable calves per year. The orca functional group was segregated from other cetaceans based partly on their diet, which consists of mammals and marine turtles in addition to marine fish (Ford et al. 1998, Ford et al. 2005). We assumed that juvenile orcas eat proportionately more fish and fewer mammals.

Vaquita (WDG)

Vaquita is a diminutive porpoise endemic to the northern Gulf of California (Jaramillo-Legorreta et al. 1999). It is restricted to a small range in the northern gulf, but historically its range may have been much larger (Leatherwood et al. 1988). The International Union for Conservation of Nature (IUCN) declared this species vulnerable in 1986, endangered in 1990, and critically endangered in 1996; today, vaquitas are on the verge of extinction (Rojas-Bracho et al. 2007) and their population appears to be on the decline, losing 17.7% of individuals per year according to Barlow et al. (1997).

Vaquitas travel in small groups; this and their elusive nature make direct population estimates from censuses difficult to obtain (Silber 1988, Gerrodette et al. 1995). As a result, previous estimates of their abundance range widely (Barlow et al. 1997). A population estimate of 567 individuals was made in 1997 (Jaramillo-Legorreta et al. 1999), but a more recent study revised that figure to 150 animals as of September 2007 (Jaramillo-Legorreta et al. 2007). Multiplying numbers by the average body weight reported in Trites and Pauly (1998) suggests a current biomass of 3.338 mt (0.0577 kg • km^{-2}) in the study area. We used a fixed recruitment relationship in Atlantis in which each female was assumed to birth 0.26 viable calves per year. The vaquita diet was based on averaged values from Morales-Zárate et al. (2004) and Lozano (2006), which were adjusted into the equivalent Atlantis groups. Diet for juveniles was assumed similar to adults.

Vaquitas are captured incidentally by a variety of net types including gill nets targeting chano, shrimp, sharks, and mackerel; they are also killed by shrimp trawl nets (D'Agrosa et al. 1995). Estimates from 1993 suggested that between 14 and 93 animals were killed annually as bycatch from fisheries (D'Agrosa et al. 2000, Rojas-Bracho et al. 2006, Jaramillo-Legorreta et al. 2007). A conservative estimate from the mid-1990s of 35 individuals killed per year (D'Agrosa et al. 1995), combined with the population estimate in 1997, leads to the calculation of a fishing mortality rate of 0.062 yr^{-1}. The population has decreased since the mid-1990s, so the encounter rate has probably decreased. For example, five incidental deaths were reported in 2000 (Pérez-Cortés and Rojas-Bracho 2000). However, we assumed that the encounter rate has decreased proportionately to population size, so we applied this same fishing mortality figure in the model.

Pinnipeds (PIN)

There are three species of pinnipeds in the northern Gulf of California: California sea lion (*Zalophus californianus*), northern elephant seal (*Mirounga angustirostris*), and harbor seal (*Phoca vitulina*). The population of California sea lions was estimated in 1983 to be 30,000 individuals (Le Boeuf et al. 1982) and in 1996 as 28,220 (Zavala-Gonzalez and Mellink 1997), but their numbers are thought to have diminished and are now at 20,000 (Lluch-Cota 2004); they occur mainly in the northern gulf study area. Assuming a 50:50 population of males to females and average body weights reported in Trites and Pauly (1998) suggests a total biomass of 1,477 mt. These are the most abundant pinnipeds in the study area (Lluch-Cota 2004).

Recent surveys of northern elephant seals were compiled by Mesnick et al. (1998); they determined there was a small population of animals in the gulf, only 22 individuals have been sighted since the late 1970s, of which 17 were sighted in the study area. Assuming that this number is representative of the number of resident individuals, and assuming a 50:50 population of males and females and average body weights reported in Trites and Pauly (1998) suggests a total biomass of 6.3 mt. Assuming that the biomass of harbor seals is negligible, we calculated a pinniped biomass of approximately 1,483 mt for the whole study area. We used a fixed recruitment relationship in Atlantis in which each female was assumed to birth 0.35 viable pups per year. Diet for pinnipeds was based on averaged values from Morales-Zárate (2004) and Lozano (2006), which were adjusted into the equivalent Atlantis groups. Juveniles were assumed to eat similar items as adults in similar proportions.

Anthropogenic mortality among California sea lions is caused largely by entanglement in fishing gear, but some intentional captures and killings may also contribute (Zavala-Gonzalez and Mellink 1997). Entanglement rates averaged over 10 sites in the central northern Gulf of California between 1991 and 1995 suggest an entanglement rate of 0.49% yr^{-1} per individual (Zavala-Gonzalez and Mellink 1997). We assumed a uniform weight for individuals and applied this number on a per biomass basis for adult and young adult age-classes. Fishing mortality on the pup (juvenile) age-classes was assumed to be zero, since they have little interaction with fishing gear (Zavala-Gonzalez and Mellink 1997).

Sea Turtles (SP and REP)

We divided sea turtles into two functional groups based on habitat use and feeding habits: oceanic and reef-associated. Oceanic turtles include the highly migratory species leatherback turtle (*Dermochelys coriacea*), olive Ridley turtle (*Lepidochelys olivacea*), and loggerhead turtle (*Caretta caretta*). Reef-associated turtles include the hawksbill turtle (*Eretmochelys imbricata*) and green turtle (*Chelonia mydas*). Very little information exists on turtles in the northern Gulf of California. In the absence of abundance counts, we assumed a small but arbitrary biomass concentration of 0.010 t • km^{-2} for reef-associated and oceanic species together when averaged across the entire study area (578 mt system-wide biomass). This amount is within the range typically used to represent turtles in other tropical and subtropical systems (e.g., Polovina 1984, 0.015 t • km^{-2}; Ainsworth et al. 2007, 0.02 t • km^{-2}; Gribble 2003, 0.007 t • km^{-2}; Fulton et al. 2007a, 0.001 t • km^{-2}).

Green turtles are the most abundant in the northern gulf followed by olive Ridely and loggerheads; leatherback and hawksbill turtles are the least abundant.[17] This ratio is typical of northwestern Mexico (Felger et al. 2005). We therefore assumed a 40:60 biomass split between the oceanic and reef-associated groups due to the presence of green turtles in the latter. Assuming an average weight for reef-associated turtle individuals of 135 kg (based on hawksbills at 90 kg and green at 180 kg) suggests there may be 2,560 reef associated turtles in the northern gulf. Assuming an average weight of oceanic turtles of 205 kg (based on leather back at 450 kg, loggerhead at 114 kg, and olive Ridely at 45 kg) suggests there may be 1,130 oceanic turtles in the northern gulf. We assumed fixed recruitment for both groups. Oceanic and reef-associated turtle females are said to produce 0.27 and 0.6 viable hatchlings per year, respectively. These values produced reasonable population growth rates in the absence of fishing mortality.

Information on seasonal migrations of turtles within the Gulf of California is very sparse, with only one individual tagged to date, but the period of greatest activity in the gulf may correspond to periods of warm water, from May to October.[18] We assumed this holds for all species. There have been confirmed nesting sites in the northern Gulf of California for olive Ridley and leatherback turtles (Seminoff and Nichols 2006) and these are likely the only two species that nest in the gulf. However, the main importance of the area is probably for foraging. We assumed reef turtles feed mainly on algae, invertebrates, and gelatinous prey.

This group also includes hawksbill turtles, which feed on sponges (Seminoff and Nichols 2006) and eel grass (Grismer 2002). Diet of juvenile reef turtles, we assumed, contains more animal matter than the adult because of the ontogenetic preferences of green turtles (Arthur et al. 2008, Lopez-Mendilaharsui et al. 2008). The diet of juvenile oceanic turtles was based on loggerheads, which eat mainly crabs and lobsters, marine snails, and other benthic invertebrates (Boyle and Limpus 2008), while diet of adult oceanic turtles includes mainly cephalopods and pelagic jellies, with some pelagic fish present (Revelles et al. 2007). Less is known about the diets of leatherback and olive Ridley turtles, although leatherbacks are suggested to feed at a lower trophic level than loggerheads (Godley et al. 1998).

The survival of loggerhead turtles was estimated as 0.8613 yr^{-1} by Chaloupka and Limpus (2002). Natural mortality is calculated using the relation $M = -\ln S$ to be 0.149 yr^{-1}. The survival estimate of green turtles, 0.984 yr^{-1}, is from Mortimer et al. (2000) which we converted to natural mortality using the same method: 0.016 yr^{-1}. Values for these two species were assumed representative of oceanic and reef-associated groups, respectively. Turtles, particularly green turtles, were hunted for food until 1990, when a moratorium on targeted captures went into effect (there was also a brief ban between 1971 and 1973) (Aridjis 1990, Diario Oficial de la Federación 1990, Seminoff and Nichols 2006). Some level of incidental

[17] P. A. Valdivia-Jimenez, CEDO, Puerto Peñasco, Sonora, Mexico. Pers. commun., 23 July 2008.
[18] J. Seminoff, SWFSC, La Jolla, CA. Pers. commun., 23 July 2008.

captures in fisheries continues despite implementation of turtle excluder devices and other gear modifications (Lluch-Cota et al. 2007). No reliable estimates of fishing mortality were available, so we assumed that fishing mortality is responsible for 5% of the total mortality rate in the northern gulf for reef-associated turtles. Leatherbacks are at particular risk from longline and drift-net fisheries (Seminoff and Nichols 2006), so we assumed that the oceanic functional group suffers a greater amount of fishing mortality equivalent to 10% of the total mortality rate. These estimates of natural and fishing morality were used to establish initial age structure in the model.

Sea Birds (SB)

Approximately 146 species of sea birds occupy or transverse the northern Gulf of California (Brusca et al. 2005), and it is an important breeding area for many species (Peresbarbosa and Mellink 1994, Mellink et al. 1996). It would be an appropriate distinction in the functional group structure to divide this group into surface feeding sea birds (e.g., Laridae) and diving birds; however, the fixed number of model vertebrate groups in Atlantis prohibited this.

The sea birds functional group therefore includes the gannets (Sulidae, blue-footed booby [*Sula nebouxii*], brown booby [*S. leucogaster*]), the gulls (Laridae, Heerman's gull [*Larus heermanni*], California gull [*L. californicus*], yellow-footed gull [*L. livens*], the only endemic species [Brusca et al. 2005], ring-billed gull [*L. delawarensis*]), the terns (Sternidae, elegant tern [*Thalasseus elegans*], royal tern [*T. maximus*], Forster's tern [*Sterna forsteri*]), the storm-petrels (Hydrobatidae, black storm-petrel [*Oceanodroma melania*], least storm-petrel [*Halocyptena microsoma*]), the cormorants (Phalacrocoracidae, Brandt's cormorant [*Phalacrocorax penicillatus*] and double crested cormorant [*P. auritus*]), the frigatebirds (Fregatidae, magnificent frigatebirds [*Fregata magnificens*]), the loons (Gaviidae, common loon [*Gavia immer*], Pacific loon [*G. pacifica*]), the oystercatchers (Haematopodidae, American oystercatcher [*Haematopus palliatus*]), the herons (Ardeidae, snowy egrets [*Egretta thula*], reddish egret [*E. rufescens*], great egret [*Ardea alba*], great blue heron [*A. herodias*]), the sandpipers (Scolopacidae, whimbrel [*Numenius phaeopus*], least sandpiper [*Calidris minutilla*], black turnstone [*Arenaria melanocephala*]), the pelicans (Pelecanidae, brown pelicans [*Pelecanus occidentalis*]), the shearwaters (Procellariidae, sooty shearwaters [*Puffinus griseus*], flesh-footed shearwater [*P. carneipes*]), the grebes (Podicipedidae, eared grebes [*Podiceps nigricollis*]), and the auks (Alcidae, Craveri's murrelet [*Synthliboramphus craveri*]). We have used a fixed recruitment relationship. Initially, females were assumed to lay 8 viable eggs per year, but model dynamics required that this be reduced to 0.31, possibly to account for prehatching mortality not explicitly covered in the model.

There is very little information available on the relative abundance of these species. However, the most common species include the double crested cormorant, ring-billed gull, frigates, and pelicans; in the winter, grebes are common as are loons.[19] In an area approximately one-fourth of the Colorado River delta, Mellink et al. (1997) estimated 104,675 aquatic birds were present during winter sampling, noting that the numbers decreased to 540 during summer.

[19] A. Rosemartin, CEDO, Puerto Peñasco, Sonora, Mexico. Pers. commun., September 2008.

Taking the winter count and assuming an average weight of 500 g per bird suggests about 52 mt of biomass.

The area they studied represents about 42 km of coastline (stick size ≈ 0.5 km). Scaling to represent the entire study area coastline of 1,419 km and assuming that the Colorado River delta has a bird concentration equal to twice the average amount per unit shoreline suggests a winter biomass of 874.3 mt for the northern Gulf of California. By unit area, this equates to 0.015 t • km^{-2} for the northern gulf. The value is very close to the estimates made by Arreguin-Sánchez et al. (2002) (0.013 t • km^{-2}) and Rosas-Luis et al. (2008) (0.01 t • km^{-2}). Because of the uncertainty of relative abundance and migration patterns within this speciose group, and because of the diversity of feeding habits and habitats represented, we chose to use a generalist diet in Atlantis based on average diet values given in Lozano (2006) and Arreguin-Sánchez et al. (2002), which we converted to our group equivalents. We assumed young birds eat similar items.

More than 200 species of birds migrate along the west coast of Mexico (Patten et al. 2001) but there is almost no information on geographic distribution in this region (Glenn et al. 2006). Data from Mellink et al. (1997) suggest that the summer abundance decreases to 0.5% of winter abundance. Indeed, we know that for many bird species there is a decrease in the amount of available food during this time as warmer temperatures cause a descent of the thermocline, reducing ocean productivity in surface layers and causing fish to dwell deeper, out of reach of sea birds (Vieyra et al. 2009). We assumed that the birds begin to migrate into the study area in late summer (August) and leave the area in late spring (May). The decrease in the flow of the Colorado River may have reduced the amount of refuge habitat available for migratory birds.

Scallops and Penshells (BC)

The group scallops and penshells represents callo, commercial bivalves of special interest to PANGAS studies. Included are six species identified in Cudney-Bueno and Turk-Boyer (1998): Spiny rock scallop, aka Callo de escarlopa (*Spondylus calcifer*); Pacific throny oyster, aka Callo mechudo (*S. princeps*); Pacific winged pearl oyster, aka Callo de árbol (*Pteria sterna*); pen shell scallop, aka Callo de hacha (*Pinna rugosa*); pen shell, aka Callo de riñón (*Atrina tuberculosa*); and pearl oyster, aka Madreperla (*Pinctada mazatlanica*). Biomass in the study area was estimated to be 1,292 mt (0.022 t • km^{-2}) based on PANGAS transects and interpolated using the biomass allocation algorithm. This biomass yields a reasonable fishing mortality for this group (0.11 yr^{-1}) with respect to the estimated catches in the 2008 model (143 mt). Scallops and penshells were assumed to eat large and small phytoplankton, large and small zooplankton, refractory detritus, and pelagic bacteria. Biomass was allocated to the sediment layer (Atlantis code: Benthic_Carniv_N).

Penaeid Shrimp (BD)

This group includes large-bodied shrimps of the family Penaeidae, which are commonly cultured and captured throughout the world. Five such species are identified as present in the northern Gulf of California according to Findley and Brusca (2005), however, blue shrimp (*Litopenaeus stylirostris*) was allocated into its own functional group, juvenile/adult blue shrimp, due to its commercial importance. Penaeid shrimp therefore consists of four species: pink shrimp (*Penaeus duorarum*), brown shrimp (*P. californiensis*), white shrimp (*P. setiferus*), and rock shrimp (*Sicyonia penicillata*). Biomass for this group was available from Nava-Romo (1994), who collected brown shrimp and rock shrimp in sampling cruises, and Lopez-Martinez et al. (1999), who used an age-structured model to estimate rock shrimp biomass.

Sum biomass from Nava-Romo (1994) for both species equates to 1,797 mt for the northern gulf, but we consider that unrealistic relative to recorded catches in the Anuario Estadistico, which average 1,282 mt per year since 2005. Lopez-Martinez et al. (1999) suggested that the rock shrimp biomass alone might be as high as 10,000 mt. Assuming that value for rock shrimp and an additional 32,863 mt for brown shrimp from Morales-Bojorquez et al. (2001), we calculate penaeid shrimp biomass as approximately 42,863 mt and apply this in the model (0.742 t • km^{-2}). This estimate is higher than the biomass value used by Morales-Zarate et al. (2004) for brown and rock shrimp combined (15,259 mt), but less than the estimate of Lozano (2006) (63,522 mt). We assumed the diet of these species is similar to blue shrimp, consuming mainly shrimp, zooplankton, benthos, detritus, macroalgae, and microalgae (Martinez-Cordova and Pena-Messina 2005).

Sea Cucumbers (BFD)

Diet was based partly on the giant sea cucumber (*Isostichopus fuscus*), which feed on organic matter and algae, from data in Toral-Granda (1996) as cited in Hearn et al. (2005). Biomass in the study area was estimated to be 17,956 mt based on PANGAS transects, Thomson and Mesnick (1993) and Thomson et al. (1996), interpolated using the biomass allocation algorithm. This equates to a system average of 0.311 t • km^{-2} or an average nitrogen concentration of 54.5 mg N • m^{-3} in occupied polygons. Biomass was allocated to the sediment layer (Atlantis code: Filter_Deep_N). Diet was set similarily to Lozano (2006); components are seagrass, macroalgae, and detritus, which we assumed to consist of 60% carrion and 40% labile detritus.

Sessile Invertebrates (BFF)

Biomass in the study area of ascidians, sponges, and barnacles was estimated to be 28,017 mt based on PANGAS transects, ISPM transects, and Nava-Romo (1994), interpolated using the biomass allocation algorithm. This equates to a system average of 0.485 t • km^{-2} or an average nitrogen concentration of 92.2 mg N • m^{-3} in occupied polygons. Biomass was allocated to the sediment layer (Atlantis code: Filter_Other_N). Diet of sessile invertebrates was patterned after coral and anemones; it consists of large and small phytoplankton, large and small zooplankton, refractory detritus, and pelagic bacteria.

Crabs and Lobsters (BFS)

Crab and lobster biomass in the study area was estimated to be 42,295 mt based on ISPM transects and Nava-Romo (1994), interpolated using the biomass allocation algorithm. This equates to a system average of 0.732 t • km^{-2} or an average nitrogen concentration of 144.6 mg N • m^{-3} in occupied polygons. Biomass was allocated to the sediment layer (Atlantis code: Filter_Shallow_N). Diet for this group was based on the adult diets of blue spiny lobster (*Panulirus inflatus*) and green spiny lobster (*P. gracilis*), which Lozano-Alvarez and Aramoni-

Serrano (1997) estimated from a region south of the study area. Diet of juvenile lobsters was also factored in based on samples of California spiny lobster (*P. interruptus*) taken by Casteneda-Fernandez de Lara et al. (2005) from the Pacific coast of Baja California. Diet for the group was taken as the weighted average of these adult and juvenile examples, with adult receiving twice the relative weighting of juveniles.

Herbivorous Echinoderms (BG)

Biomass in the study area was estimated to be 76,212 mt based on PANGAS transects, Thomson and Mesnick (1993), and Thomson et al. (1996), interpolated using the biomass allocation algorithm. This equates to a system average of 1.319 t • km^{-2} or an average nitrogen concentration of 256.8 mg N • m^{-3} in occupied polygons. Biomass was allocated to the sediment layer (Atlantis code: Benthic_grazer_N). Herbivorous echinoderms like urchins may be less important in the grazing of algal communities in the Gulf of California than parrotfishes and surgeonfishes (Montgomery et al. 1980). Diet was set to include macroalgae and microphytobenthos only.

Macrobenthos (BMD and BML)

All benthic invertebrates not elsewhere included were categorized into one of two functional groups, carnivorous macrobenthos or infaunal/epifaunal meiobenthos. The Atlantis designations for carnivorous macrobenthos and infaunal/epifaunal macrobenthos are BMD and BML, respectively. Diet for carnivorous macrobenthos was set to include the following benthic invertebrate and detritus groups: infaunal/epifaunal meiobenthos, scallops and penshells, sea cucumbers, sessile invertebrates, crabs and lobsters, herbivorous echinoderms, carnivorous macrobenthos, bivalves, snails, blue crab, and labile and carrion detritus. Diet for infaunal/epifaunal meiobenthos includes: microphytobenthos, infaunal/epifaunal meiobenthos, snails, benthic bacteria, and labile and carrion detritus.

Biomass in the study area for carnivorous macrobenthos was estimated to be 220,538 mt based on PANGAS transects, ISPM transects, Thomson and Mesnick (1993), Nava-Romo (1994), and Thomson et al. (1996), interpolated using the biomass allocation algorithm. This equates to a system average of 3.816 t • km^{-2} or an average nitrogen concentration of 761.1 mg N • m^{-3} in occupied polygons. Biomass was allocated to the sediment layer (Atlantis code: Macrobenth_Deep_N). Diet for carnivorous macrobenthos was estimated based on the diet of California two-spot octopus (*Octopus bimaculatus*) (Ambrose 1984).

Biomass in the study area for infaunal/epifaunal meiobenthos was estimated to be 481,735 mt based on ISPM transects and Nava-Romo (1994), interpolated using the biomass allocation algorithm. This equates to a system average of 8.335 t • km^{-2} or an average nitrogen concentration of 1671.5 mg N • m^{-3} in occupied polygons. Biomass was allocated to the sediment layer (Atlantis code: Megazoobenthos_N).

Bivalves (BMS)

Before the numerous dams were constructed on the Colorado River, the invertebrate assemblage in the northern gulf was dominated by the Colorado delta clam; as many as 91% of bivalve fauna consisted of this species and 4% consisted of the white clam (Veneridae).

Presently, that ratio has been reversed: 87% of the shells are white clam with only 5% Colorado delta clam, as estimated by analyzing cheniers, shell rich deposits lining the beaches in the northern gulf (Flessa et al. 2001). The assemblage shift is thought to be due to changes in salinity or possibly nutrient influx (Rodriguez et al. 2001). Other major bivalve species found in the northern gulf include the Pacific calico scallop, aka catarina scallop (*Argopecten ventricosus*) (Cárdenas and Aranda 2000, Caceres-Martinez et al. 2005). Diet information for this group was based on qualitative remarks regarding larval Pacific calico scallop and larval Pacific winged pearl oyster, based on laboratory feeding experiments (Lora-Vilchis and Maeda-Martinez 1997, Martinez-Fernandez et al. 2004). On this basis we considered likely diet items to include large and small zooplankton, large and small phytoplankton, and microphytobenthos, with a small amount of refractory detritus and pelagic bacteria.

Biomass in the study area was estimated to be 276,550 mt based on PANGAS transects, interpolated using the biomass allocation algorithm. This equates to a system average of 4.785 $t \cdot km^{-2}$ or an average nitrogen concentration of 889.3 $mg\ N \cdot m^{-3}$ in occupied polygons. Biomass was allocated to the sediment layer (Atlantis code: Macrobenth_Shallow_N).

Snails (BO)

The snails group includes all members of class Gastropoda. According to Findley and Brusca (2005), there are 1,111 species in the northern gulf from 396 genera and 340 families. These include members of the following orders: Anaspidea, Basommatophora, Cephalaspidea, Gymnophila, Heterostropha, Neotaenioglossa, Notaspidea, Nudibranchia, Patellogastropoda, Sacoglossa, and Thecosomata. Diet was assumed to consist of microphytobenthos, detritus, and a small amount of bacteria and macrophytes.

The main commercial species of snails (aka caracol) in Baja California are the wavy turban snail (*Megastraea undosa*), turban snail, aka caracol panocha (*Megastrea turbanica*), caracol chino rosa (*Phyllonotus erhythostoma*), and black murex, aka caracol chino negro (*Hexaplex [Muricanthus] nigritus*, (Diario Oficial de la Federación 2004a). Stock assessment suggests a standing biomass of about 200 mt for caracol panocha in Baja California Sur (BCS) (Diario Oficial de la Federación 2004a). The BCS stock is likely a different population from the one in the Sonora study area. Sonora yields approximately one-fourth as much catch as BCS, and if that ratio is representative of total relative biomass, then there may be 50 mt of caracol panocha in the study area. That amount can probably be multiplied by several times to represent the biomass of commercial species combined; however, this is insignificant next to the biomass of noncommercial species. Biomass was estimated as 5,223 mt (0.09 $t \cdot km^{-2}$) based on Nava-Romo (1994) and PANGAS transects, and interpolated using the biomass allocation algorithm. This estimate yields a reasonable fishing mortality for this group (0.249 yr^{-1}) with respect to the estimated catches in the 2008 model (940 mt). Biomass was allocated to the sediment layer (Atlantis code: Meiobenth_N).

Juvenile and Adult Blue Crab (CEP)

This group includes warrior swimming crab, aka blue crab (*Callinectes bellicosus*); it has been divided into juvenile and adult ontogenetic split pools. The biomass of blue crab from stock assessments for Sonora and Sinoloa is approximately 95,000 mt (INAPESCA 2006b); we assumed that 50% of the stock occurs in the study area, 47,500 mt, and that this is representative of the adult pool. Juvenile blue crab was assumed to constitute 25% of adult biomass. Average biomass per polygon for adults and juveniles is therefore 0.693 t • km^{-2} and 0.173 t • km^{-2}, respectively. The combined biomass, 0.866 t • km^{-2}, falls in between crab biomasses for the northern gulf used by Lozano (2006) (1.162 t • km^{-2}) and Morales-Zárate et al. (2004) (0.053 t • km^{-2}). The average nitrogen concentrations for adults and juveniles equal 108.7 mg N • m^{-3} and 27.2 mg N • m^{-3} in occupied polygons (Atlantis codes: Cephalopod_N1 and Cephalopod_N2)[20]. Biomass was assigned to the sediment layer. Diet for the adult group was based on the related species, arched swimming crab (*C. arcuatus*) and giant swimming crab (*C. toxotes*); we used average values from samples taken in Pacific Mexico (Paul 1981). We assumed juveniles have similar diets, but with proportionately more meiobenthic items and fewer bivalves and crabs.

Macroalgae (MA)

There are at least 140 taxa of marine algae in the northern Gulf of California (Aguilar-Rosas et al. 2000). The most abundant red alga (Rhodophyta) is *Gracilariopsis lemaneiformis*, the dominant brown algae (Phaeophyceae) are *Sargassum johnstonii*, *S. herporhizum*, *S. Sinicola*, *Colpomenia peregrina*, and *Chondracanthus pectinatus* (Pacheco-Ruíz et al. 1999), and the dominant green algae (Chlorphyta) are *Cladophora prolifera* and *Struveopsis robusta* (Aguilar-Rosas et al. 2000). Coastal vegetation plays an important role in providing refuge habitat for young age-classes of fish. For example, the biomass density of *Sargassum* spp. has been linked to the recruitment success of leopard grouper (Aburto-Oropeza et al. 2008a). *G. lemaneiformis* is the main alga harvested in the Gulf of California; the product is shipped entirely to Japan (Pacheco-Ruíz et al. 1999). Another commercial rhodophyte is *C. pectinatus* (Readdie et al. 2006). Both species are harvested for their agar and carrageenan.

Maximum biomass of *G. lemaneiformis* occurs in the spring, and was estimated by field sampling in 1995 at approximately 6.766 ± 0.475 dry mt per kilometer of coastline (Pacheco-Ruíz et al. 1999). In 1996 the biomass was 30% lower, about 4.776 ± 0.289 dry mt per kilometer of coastline. Averaging these values to 5.771 t • km^{-2} and multiplying by the coastline of the study area, 1,419 km (calculated using a stick size of >10 km), suggests there are about 8,190 mt of *G. lemaneiformis* in the northern Gulf of California during spring. Using 1995 as a reference point, the summer, autumn, and winter months show lower biomasses: about 1%, 5%, and 35% of maximum, respectively (Pacheco-Ruíz et al. 1999). Initial conditions used in the Atlantis model represent the ecosystem as on January 1, so we assumed the standing crop of *G. lemaneiformis* is 35% of that value, 2,867 mt.

Pacheco-Ruíz et al. (1999) reported typical biomasses for other brown and green algae from temperate regions of the world and suggested that the Gulf of California might be similar. Summing median values provided for the genera Laminara, Ecklonia, Macrocystis, Ascophyllum, and Fucus results in 10.75 kg wet wt • m^{-2}, which is about 2.75 times the biomass density of *G. lemaneiformis*. Therefore, assuming similar area coverage, the total biomass of the dominant Rhodophyte *G. lemaneiformis* and other dominant species combined is close to 2,867

[20] Cephalopod designation is a holdover from Bay Model 2 (Fulton 2001, Fulton et al. 2004a).

+ 2.75(2867) = 10,751 mt, or 0.186 t • km^{-2} when averaged over the entire study area. This equates to an average nitrogen concentration of 121 mg N • m^{-2} in occupied coastal polygons. Note that concentrations in reef areas alone are much higher: heavily grazed reefs can contain algal mat standing crop densities of 1.1 t • km^{-2}, while densities on lightly grazed reefs may be 327 t • km^{-2} or higher (Montgomery et al. 1980). The total biomass of algae was divided among Atlantis polygons as follows. Occupied range was determined based on community interview information held in the PANGAS database and stored in GIS shapefiles (Moreno-Baez unpubl. data). Assuming constant density in occupied areas, the biomass of algae in each polygon was assumed proportional to the total area covered by algae in each polygon.

Seagrass (SG)

The seagrass group includes vascular marine plants such as seagrass, halophytes, and mangroves. Most seagrass in the northern Gulf of California is found in estuaries, which occupy a significant portion of the coastal reaches (about 170,000 hectares in the study area). Gulf estuarine environments are particularly dominated by saltgrass (*Distichlis palmeri*) marshes (Glenn et al. 2006). Seagrass is found in deep, sandy, and sheltered bays. Main concentrations are along the south and east coasts of Isla Tiburon, Canal el Infiernillo (separating Isla Tiburon from the Sonoran mainland), and Bahia Kino.[21]

There tends to be more seagrass biomass in the south of the study area than in the north; the north has less suitable habitat because its shallow bays and estuaries tend to desiccate at low tide and there are few areas sheltered from the significant tidal currents. There tends to be more seagrass biomass on the east coast of the gulf than the west coast; the west coast, including Isla Angel de la Guarda, Bahia de Los Angeles, and the San Lorenzo archipelago, has fewer suitable sandy areas.[22] To determine the relative coverage of seagrass in Atlantis polygons, we assumed that 70% of the biomass was located in the east and 30% in the west; we also assumed that 80% was located in the south and 20% in the north. A weighting factor for each quadrant of the map was determined as the cross product of these ratios (e.g., the south-east quadrant had the highest relative biomass at $0.8 \times 0.7 = 0.56$). These factors were applied to all polygons that have seagrass, then normalized; the resulting score indicates relative biomass. Coastal polygons containing seagrass were determined based on the occurrence of halophytes (Glenn et al. 2006), and expert communication. The seagrass distribution was next modified according to the occurrence of mangroves.

Most of the mangrove biomass in the Gulf of California occurs south of our study area; however, Bahia Kino and Canal el Infiernillo (Atlantis polygons 6 and 20) contain some mangroves (Aburto-Oropeza et al. 2008b). The amount of biomass is uncertain, so we increased the relative concentration of this functional group in the two corresponding polygons by an additional 20% over the concentration determined for seagrasses. This revised distribution was translated into absolute biomass values by adopting the rough system-wide estimate of biomass density for the northern gulf used by Lozano (2006), which is 0.745 t • km^{-2}. This equates to

[21] R. Loaiza-Villanueva and S. Perez-Valencia, CEDO, Puerto Peñasco, Sonora, Mexico. Pers. commun., March 2008.
[22] See footnote 2.

43,061 mt for the study area, about 303.6 mg N • m^{-2} in occupied polygons. Mangrove forests are thought to provide feeding areas and protection for juvenile fish (Aburto-Oropeza et al. 2008b).

Phytoplankton and Phytobenthos (PL, PS, and MB)

Phytoplankton was divided based on size into two functional groups, large and small phytoplankton. Large phytoplankton includes primarily planktonic diatoms, of which 18 species are estimated to be present in the Gulf of California in the genus *Thalassiosira*, with *T. eccentrica* being the most widespread (Hernández-Becerril and Pena 1995), one species of *Nitzchia*, and at least four species of genus *Pseudo-nitzschia*, with *P. pungens* being the most widespread (Hernández-Becerril 1998). The small phytoplankton group includes blue-green algae (cyanophyta), dinoflagellates, and microchlorophytes. Atlantis designations for large and small phytoplankton are PL and PS, respectively. The group microphytobenthos is comprised of cellular and colonial photosynthetic organisms affixed to substrate (Atlantis designation, MB).

Phytoplankton biomass for the northern gulf was based on Santamaría-del-Angel et al. (1994); those authors credit the following sources: unpublished data (later published in Alvarez-Borrego 2003), Gendrop-Funes et al. (1978), Alvarez-Borrego and Gaxiola-Castro (1988), Valdez-Holguin (1986), Bazán-Guzmán (1990), and Millán-Núñez et al. (1993). Santamaría-del-Angel et al. (1994) divided the Gulf of California into 14 biogeographic regions based on the results of a principal component analysis of pigment time series data, 8 of which overlap with the present study area (Figure 10); 33 locations were sampled by remote sensing using the Coastal Zone Color Scanner.

Using GIS, we determined the composition of Atlantis polygons with respect to the bioregions. With the resulting matrix, we were able to determine average chlorophyll concentrations in each polygon, assuming median values for bioregions where a range of values were provided. We converted units of mg of dry weight of chlorophyll per cubic meter of seawater to phytoplankton wet weight biomass using relationships in Vörös and Padisak (1991); those relationships were based on freshwater species, but such ratios may be consistent across taxa (Desortová 1981). That amount was converted to dry weight using ratios in Cushing et al. (1958) and reduced to represent nitrogen and silcon, respectively, using the Redfield ratio. We assumed that diatoms constitute 75% of phytoplankton biomass (Atlantis code: Diatom_N and Diatom_S), while picophytoplankton constitutes 25% (Bruland et al. 2001, Brand et al. 2007) (Atlantis code: PicoPhytopl_N). This procedure provided surface concentrations, which we then allotted to depth zones assuming a similar distribution as chlorophyll *a*, averaged over several periods and sampling locations in the northern gulf (Hernandez-Becerril 1987, Alvarez-Borrego and Gaxiola-Castro 1988, Gaxiola-Castro et al. 1999).

Dinoflagellate cell counts at depth for the study area were taken from Alvarez-Borrego and Gaxiola-Castro (1988) and converted to nitrogen concentrations assuming 1,333.5 mg N • $cell^{-1}$, the median ratio presented in Menden-Deuer and Lessard (2000) (Atlantis code: DinoFlag_N). We assumed the nitrogen concentration of microphytobenthos is 5 mg N • m^{-3} in the sediment layer and 0.1 mg N • m^{-3} in other depth layers after Brand et al. (2007) (Atlantis code: MicroPB_N). We assumed the silicon concentration of microphytobenthos is 15 mg

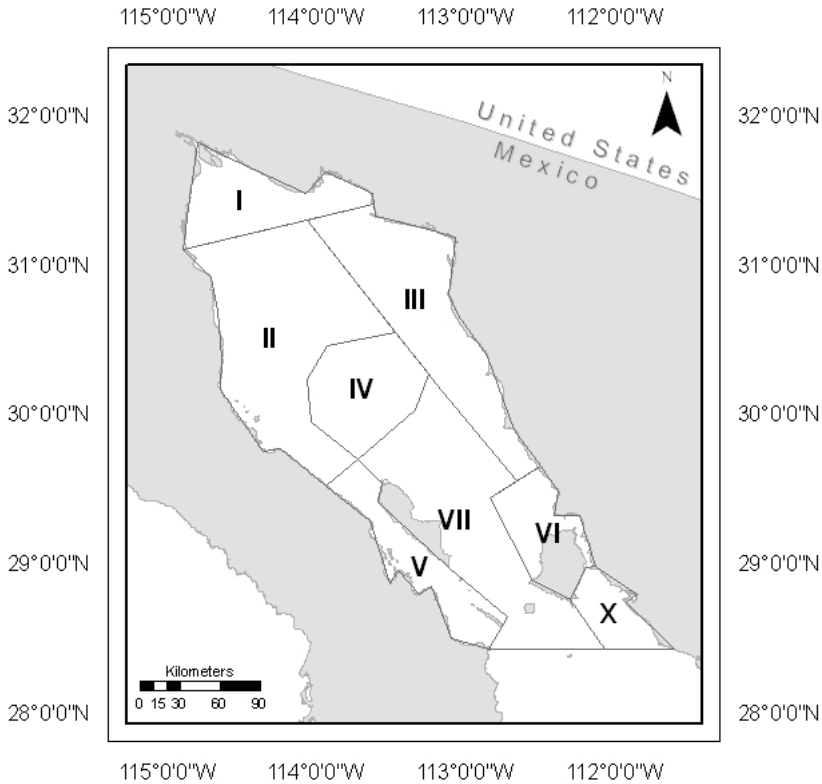


Figure 10. Biogeographic regions of the northern gulf, based on principle components analysis of pigment concentration time series at 33 locations. Adapted from from Santamaría-del-Angel et al., copyright 1994, with permission from the American Geophysical Union.

Si • m^{-3} in the sediment layer and 0.3 mg Si • m^{-3} in other depth layers after Brand et al. (2007) (Atlantis code: MicroPB_S).

Juvenile and Adult Blue Shrimp (PWN)

The blue shrimp group represents the species *Litopenaeus stylirostris* exclusively. The target species of the most profitable fishery in the northern gulf, it represents the largest shrimp species caught by volume (Aragón-Noriega and Calderón-Aguilera 2000). Blue shrimp were divided into juvenile and adult pools using Atlantis' optional ontogenetic group structure. Diet was based on blue shrimp, which mainly consume zooplankton and benthos in the wild (Martinez-Cordova et al. 2003) in addition to organic detritus, shrimp, macroalgae, and microalgae (Martinez-Cordova and Pena-Messina 2005) and organic particles colonized by bacteria (Cuzon et al. 2004). Juveniles of this group (PWNj) were assumed to consume relatively more detritus and less benthos than the adults (PWN).

Adult group biomass was taken after García-Juárez et al. (2009) as 21,323 mt for the northern gulf, which equates to 0.369 t • km^{-2}. This is less than the value used by Morales-Zárate et al. (2004), 52,020 mt, and Lozano (2006), 41,616 mt. However, this amount yields a fishing mortality of 0.55 yr^{-1} when compared to catch statistics in the Anuario Estadistico, which average 11,784 mt per year since 2005. This describes a productive, yet fully exploited stock.

Juvenile biomass was based on the postlarval biomass estimated by Galindo-Bect (2003) for the Upper Gulf Biosphere Reserve. Since these authors sampled only in the bosphere reserve, we increased the total biomass by 20% to represent juvenile shrimp that occur elsewhere in the northern gulf; the total is 6,000 mt. This assumed that the northern gulf is a productive area for shrimp and that the reserve functions as a rearing ground.

Landings for this and other Penaeid shrimp species show a significant positive correlation with lagged Colorado River discharge (Aragón-Noriega and Calderón-Aguilera 2000, Galindo-Bect et al. 2000). A number of causative mechanisms have been proposed to explain the improved recruitment following discharge events. The enlarged nursery hypothesis (Garcia 1991) contends that the estuarine area suitable for rearing Penaeid shrimp increases after a large discharge event due to active sedimentation and an increase in food availability. Another possible mechanism is that the increased river runoff augments the salinity gradient leading towards the open sea, providing the necessary cue to simulate migration from juvenile rearing areas (Garcia 1991). A large river flow event as caused by periodic flood events or experimental release (Bureau of Reclamation 2008, USDI 2008) may also temporarily increase turbidity and provide refuge for juvenile shrimp from their predators, improving survival during a critical life stage (Penn and Caputi 1986).

Large and Small Zooplankton and Jellyfish (ZL, ZS, and ZG)

Zooplankton was divided in the Gulf of California model into three functional groups: large and small zooplankton and jellyfish. There are 13 species in the large zooplankton functional group. These include species of the euphausiid genera *Euphausia, Nematobranchion, Nematoscelis*, and *Nyctiphanes*, with the most abundant species being *Nyctiphanes simplex* and *Nematoscelis difficilis* (Lluch-Cota et al. 2007). Also included in this group are the mysid genera *Boreomysis* and *Petalophthalmus*, the ctenophore genera *Beroe*, *Velemen*, and *Pleurobrachia*, and the chaetognath genera *Flaccisagitta* and *Mesosagitta*. The small zooplankton group is composed mainly of copepods, of which *Calanus pacificus* and *Rhincalanus nasutus* are highly abundant species in the gulf (Lluch-Cota et al. 2007).

The jellyfish functional group includes 14 species of siphonophora from 8 families. Atlantis designations for large zooplankton, small zooplankton, and jellyfish are ZL, ZS, and ZG, respectively. Diet of large zooplankton was assumed to consist of small zooplankton, large and small phytoplankton, with a small amount of refractory detritus, microphytobenthos, and pelagic bacteria. Diet of small zooplankton was assumed to consist of small phytoplankton, with a small amount of refractory detritus, microphytobenthos, and pelagic bacteria. Diet of jellyfish was assumed similar to filter feeding Scyphomedusa (Larson 1991), which consists of large and small zooplankton, with a small amount of jellyfish and macroalgae.

Zooplankton biomass in the area around the Colorado River delta was estimated by Farfán and Alvarez-Borrego (1992) to range 1–154 mg (dry weight) m^{-3}. Taking the median value and assuming a 1:20 ratio of dry to weight suggests 1.55 g • m^{-3}. The delta may be high in primary productivity because of the availability of nutrients. Assuming that only coastal polygons in the study area were populated at this density, there would be about 2.2 million mt of zooplankton, which equates to a system average of 37.96 t • km^{-2}. This is very close to the value used by Morales-Zárate et al. (2004), 39.46 t • km^{-2}, and is similar to the values used by Lozano

(2006) and Arreguin-Sánchez et al. (2002) at 26.33 t • km^{-2} and 20.18 t • km^{-2}, respectively. We assume that this average concentration is representative of the study area as a whole, then distribute 60% of the biomass in coastal polygons and the remaining 40% among deeper polygons. Fifty percent of the biomass is assigned to the large zooplankton group and 50% to the small zooplankton group.

An alternate estimate of zooplankton biomass in January is available from the central Pacific coast of Mexico from 1995 (prior to the 1997 El Niño), which is equivalent to approximately one-third of our density value (Franco-Gordo et al. 2004). For comparison, a summer biomass estimate (June 1993) was available from Färber-Lorda (2004) representing the oceanic mouth of the Gulf of California, which is about 60 times lower when averaged over 33 sampling locations. Jellyfish biomass was set at 0.376 t • km^{-2} after Lozano (2006), about 21,000 mt for the entire study area; it was distributed uniformly. There is some suggestion that jellyfish abundance has been increasing of late (Bakun et al. 2009). Vertical migrations for large zooplankton was based on euphausiid behavior categorized in Smiles and Pearcy (1971) and Mackas et al. (1997), used in an earlier Atlantis model by Brand et al. (2007). Vertical migrations for jellyfish were based on Shenker (1984) and Larson (1986), also used in Brand et al. (2007).

Squid (ZM)

The squid group includes all pelagic cephalopods. Species occurring in the Gulf of California are: Humboldt, aka jumbo squid (*Dosidicus gigas*); greater argonaut, aka paper nautilus (*Argonauta argo*); flowervase jewel squid (*Histioteuthis hoylei*), shortarm gonate squid (*Loliolopsis diomedeae*), red flying squid (*Ommastrephes bartramii*), roundear enope squid (*Pterygiotheuthis giardi giardi*), purpleback squid (*Sthenoteuthis oualaniensis*), and diamond squid (*Thysanoteuthis rhombus*) (Wood and Day 2008).

Diet for this group represents the average of three previously published ecosystem studies for the region (Arreguin-Sánchez et al. 2002, Morales-Zárate et al. 2004, Lozano 2006); equivalent functional groups were assigned. Conservative biomass estimates for *D. gigas* in the central Gulf of California were offered by Nevárez-Martínez et al. (2000). The median value of their range is 86,513 mt. This amount refers to an area that we estimated to be 73,840 km^2, so the biomass density is 1.17 t • km^{-2} for this species. Note that using these same original data, Rosas-Luis et al. (2008) computed a density of 0.57 t • km^{-2}, but their methods are not provided. To account for other species, we used a larger biomass value for cephalopods as quoted in Morales-Zárate et al. (2004), 7.966 t • km^{-2}. Scaling to the study area, this equals about 460,434 mt. The Anuarios Estadistico reported 10,000 to 30,000 mt of squid catch annually since 2000 and most of this (97%) originates from Guaymas. We assumed that 10% of the catch reported in the anuarios originates from our study area, leading to a catch of about 1,500–6,000 mt per year from 2000 (2008 value is 1,185 mt). Vertical migrations were based on Young (1978).

Detritus and Bacteria (DC, DR, and DL)

Three groups of detritus are described in the Atlantis model. In order of increasing disintegratability, these are carrion (dead matter, large particles), refractory detritus (cohesive, small particles), and labile detritus (easily disassociated, small particles). Atlantis designations for these groups are DC, DR, and DL, respectively. Detrital biomass (D) was determined using an empirical relationship that relates to primary productivity and euphotic depth (Pauly et al. 1993).

$$\log_{10} D = -2.41 + 0.954 \log_{10} PP + 0.863 \log_{10} E \qquad (18)$$

where PP = primary productivity (gC • m^{-2} • y^{-1}) and E is euphotic depth (m). Euphotic depth is calculated from the Beer-Lambert-Bouguer law,

$$E = \frac{\ln I(1) - \ln I(2)}{k} \qquad (19)$$

where $I(1)$ and $I(2)$ are the levels of irradiance at the surface and at the euphotic depth, respectively, and k is the light attenuation coefficient. Euphotic depth is defined as the depth at which irradiance is 1% of the irradiance at the surface. Using the light attenuation coefficient for the Gulf of California provided by Adey and Loveland (1991), 0.171 m^{-1}, and the primary productivity of Millán-Núñez et al. (1999), 115 gC • m^{-2}, we arrived at an estimate of 4.843 t • km^{-2}. We assumed that labile, refractory, and carrion detritus constitute 40%, 40%, and 20% of the total amount, respectively, so that nitrogen densities are about 361, 361, and 180 mg N • m^{-3} (Atlantis codes: Lab_Det_N, Ref_Det_N, and Carrion_N). This yields a total detritus mass estimate of 291,037 mt for the study area. We applied a nonuniform distribution in which the northwestern quadrant of the gulf was assumed to contain 30% more detritus per unit area than the remainder of the gulf due to the influence of Colorado River discharge. All detritus was assumed to occur in the sediment layer, except for labile detritus, which occurs in small quantities in the water column (1%).

Bacteria were divided into benthic and pelagic groups. Nitrogen concentration of pelagic bacteria (Atlantis code: Pelag_Bact_N) was assumed uniform at all depths and in all polygons, and equal to 0.01 mg N • m^{-3} after Brand et al. (2007); benthic bacteria (Atlantis code: Sed_Bact_N) occupy the sediment layer and have a concentration of 1.0 mg N • m^{-2} based on the same source. Both varieties of bacteria were assumed to consume refractory detritus.

Catch Reconstruction

Catch trends were developed per functional group from Mexican government statistics: the Carta Nacional pesquera (Diario Oficial de la Federación 2004b, 2006b), the Anuario Estadistico (CONAPESCA 2009), and unpublished statistics (Valdéz-Ornelas and Torreblanca unpubl. data). We also included port-level surveys (Perez-Valencia unpubl. data), fishery log books (Torre and Rojo unpubl. data), and other literature sources (Table 9). The port-level surveys were aimed at quantifying catch missing from government statistics and conducted by the PANGAS project (http://pangas.arizona.edu/en/public); surveys included interviews with individual fishermen and fishing cooperatives. These catch series are presented in Figure B-11 and Figure B-12.

Information from the Anuario Estadistico covered the major commercial species, while the unpublished information, surveys, log books, and literature sources provided estimates of catch for minor targets and bycatch species. For species that did overlap, it is unclear how much

Table 9. References consulted for catch and effort reconstruction.

Aragón-Noriega, E. 2006. Las áreas naturales protegidas como instrumento de manejo pesquero y conservación de la biodiversidad: Caso de la reserva de la biosfera del alto Golfo de California y delta del Río Colorado. *In* B. S. Faijo-Sing, S. B. Echeverria-Castro, and C. O. Tapia-Fonllem, (eds.), Desierto y mar: Estudios sociales en Sonora. Instituto Tenológico de Sonora. Guaymas, Sonora.

Arreguín-Sánchez, F., L. Beléndez-Moreno, I. M. Gómez-Humarán, R. Solana Sansores, and C. Rangel-Dávalos. 2006. Sustentabilidad y pesca responsable en Mexico. Instituto Nacional de la Pesca. Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca Y Alimentacion.

Arreguín-Sánchez, F., L. Beléndez-Moreno, I. M. Gómez-Humarán, R. Solana-Sansores, and A. Rangel-Dávalos. 2006. Sustentabilidad y pesca responsable en Mexico. Instituto Nacional de la Pesca. Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca Y Alimentacion.

Arvizu, J., and H. Chavez. 1970. Synopsis of the biology of the totoaba *Cynoscion macdonaldi* (Gilbert 1890). U.N. Food and Agriculture Organization Fisheries Synopsis 108, FAO, Rome.

Berdegue, J. 1955. La Pesqueria de la totoaba (*Cynoscion macdonaldi* Gilbert) en San Felipe, Baja California. Revista de la Sociedad Mexicana de Historia Natural, 16(1–4):45–76.

CONASPESCA (Comisión Nacional de Acuacultura y Pesca). 2009. Anuario estadistico de acuacultura y pesca (1980–2000). Online at http://www.conapesca.sagarpa.gob.mx/wb /cona/1980_1989 [accessed 18 January 2011].

Cuellar, P. J., and C. O. Cadena, (eds.). 2006. *In* Sustentabilidad y Pesca Responsable en Mexico. Erizo de mar, p. 87–100. Insituto Nacional de la Pesca. Santa Cruz Atoyac. Delegación Benito Juárez, C.P. 03310, Mexico.

Diario Oficial de la Federación. 2004. Segunda seccion. Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion. Lunes 15 de marzo de 2004.

Diario Oficial de la Federación. 2006. Primera seccion. Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion. Viernes 25 de agosto de 2006.

Galindo-Bect, M. S. 2003. Larvas y postlarvas de camarones peneidos en el alto Golfo de California y capturas de camaron con relacion al flujo del Rio Colorado. Doctor en Ciencias en Oceanografia Costera. Facultad de Ciencias Marinas. Universidad Autonoma de Baja California, Ensenada, BC.

Galindo-Bect, M. S. 2003. Larvas y postlarvas de camarones peneidos en el alto Golfo de California y capturas de camaron con relacion al flujo del Rio Colorado. Universidad Autonoma de Baja California. Facultad de Ciencias Marinas. Instituto de Investigaciones Oceanologicas, Ensenada, BC.

Galindo-Bect, M. S., E. P. Glenn, H. M. Page, K. Fitzsimmons, L. A. Galindo-Bect, J. M. Hernandez-Ayon, R. L. Petty, J. Garcia-Hernanedez, and D. Moore. 2000. Penaeid shrimp landings in the upper Gulf of California in relation to Colorado River freshwater discharge. Fish. Bull. 98:222–225.

Lercari, D., and E. A. Chavez. 2007. Possible causes related to historic stock depletion of the totoaba, *Totoaba macdonaldi* (Perciformes: Sciaenidae), endemic to the Gulf of California. Fish. Res. 86:136–142.

Table 9 continued. References consulted for catch and effort reconstruction.

López-Martínez, J., F. Arreguín-Sánchez, R. Morales-Azpeitia, and C. Salinas-Zavala. 2002. Stock assessment and potential yield for the rock shrimp, *Sicyonia penicillata*, fishery of Bahia Kino, Sonora, Mexico. Fish. Res. 59(1–2):71–81.
Magallon-Barajas, F. J. 1987. The Pacific shrimp fishery of Mexico. Calif. Coop. Ocean. Fish. Investig. Rep. 28:43–52.
Nevárez-Martínez, M. O., M. Martínez-Zavala, C. E. Cotero-Altamirano, M. L. Jacob-Cervantes, Y. Green-Ruiz, G. Gluyas-Millan, A. Cota-Villavicencio, and J. P. Santos-Molina. 2006. *In* P. J. Cuellar and C. O. Cadena (eds.), Sustentabilidad y pesca responsable en Mexico, p. 265–301. Insituto Nacional de la Pesca. Santa Cruz Atoyac. Delegación Benito Juárez, C.P. 03310, Mexico. D.F.
Ramírez, E. G. 1967. Resumen estadistico de la captura anual de totoaba en el Golfo de California en el Pe Riodo 1929–1966. Trabajos de divulgacion. Carmona y Valle 101, 40. Piso, Mexico 7, D.F. Instituto Nacional de Investigaciones Biologico Pesqueras Secretaria de Industria y Comercio Direccion General de Pesca e Industrias Conexas Comision Nacional Consultiva de Pesca. 124 Volumen XIII.
Rodríguez-Quiroz, G. 2008. Sociedad pesca y conservacion en la reserva de la biosfera del alto Golfo de California y delta del Río Colorado. Tesis de Doctorado. CIBNOR, La Paz, Baja California Sur.
Rodríguez-Quiroz, G., and E. A. Aragón-Noriega. Unpubl. manusc. [in Spanish]. Artisanal fishing of bigeye croaker *Micropogonias megalops* (Gilbert 1890) within the biosphere reserve of the upper Gulf of California and vaquita refuge area. Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional, Unidad Sinaloa.
Rodríguez-Quiroz, G., E. A. Aragón-Noriega, M. A. Cisneros-Mata, L. F. Beltrán-Morales, and A. Ortega-Rubio. Unpubl. manusc. [in Spanish]. Artisanal shrimp fishing within the biosphere reserve of the upper Gulf of California and vaquita refuge polygon. Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional.
Rojas-Bracho, L., R. R. Reeves, A. Jaramillo-Legorreta. 2006. Conservation of the vaquita *Phocoena sinus*. Mammal Rev. 36:179–216.
Vega-Velásquez, A. 2006. Langosta de la Península de Baja California. *In* P. J. Cuellar and C. O. Cadena, (eds.), Sustentabilidad y pesca responsable en Mexico, p. 157–210. Insituto Nacional de la Pesca. Santa Cruz Atoyac. Delegación Benito Juárez, C.P. 03310, Mexico, D.F.

of the catch outlined in these supplementary materials is accounted for by the primary government data source, the Anuario Estadistico. However, by adding the two series together, we arrived at an upper estimate of total catch, which, preliminary simulations suggested, was still insufficient to cause the observed decline in many stocks. This was particularly true for reef fish species, which are targets of artisanal fisheries that likely have low reporting rates, and for which discarding might be a contributing factor in their decline.

To account for unreported catch and discards, we therefore required a correction factor for each functional group. A suggested rule of thumb is that unreported catches for finfish and elasmobranchs may be underestimated by a factor of 3, while shrimp may be underestimated by a factor of 1.5.[23] To account for total removals from the system we must account for discards as well, so the appropriate correction factors could potentially be much larger. Table 10 shows the multipliers of the catch series (applied annually from 1985 to 2008) required to achieve a decline in stock abundance suggested by the biomass trends in stock assessments, monitoring data, or the biomass reconstruction derived from Ainsworth et al. (2010).

In tuning the dynamics of the 1985 model, we assumed for all exploited groups that catch was distributed among polygons in direct proportion to biomass density. Subsequent work in developing management scenarios will use fishery utilization patterns developed by the University of Arizona based on interview information (Moreno-Báez et al. 2010).

Initial Conditions File (CDF)

Vertebrate and invertebrate concentrations per polygon were based on the biomass allocation algorithm described in the Method 1: Biomass allocation algorithm subsection above. For vertebrates, conversions from metric tons to number of individuals relied on a von Bertalanffy relationship, with species-specific length-weight parameters and natural mortality rates (Table A-3). Structural nitrogen and reserve nitrogen at age were calculated using conversion ratios developed by Marshall (unpubl. data). Invertebrate nitrogen concentrations were based directly on the results of the biomass allocation algorithm, while concentrations of other structural elements depended on conversion ratios detailed in the species description section. Some data were inherited from the Port Phillip Bay 2 Atlantis model (Fulton 2001,

Table 10. Catch multipliers used to drive the historical simulation from 1985 to 2008.

Resolved groups (1–5 spp.)	Multiplier	Aggregated groups (>5 spp.)	Multiplier
Guitarfish	7.0	Grunts	25.0
Gulf grouper	5.0	Groupers and snappers	18.0
Gulf coney	4.5	Large reef fish	14.0
Extranjero	4.5	Scallops and penshells	14.0
Herbivorous fish	4.0	Skates, rays, and sharks	11.0
Leopard grouper	3.9	Lanternfish and deep	8.0
Mojarra	3.5	Drums and croakers	6.4
Small migratory sharks	2.6	Flatfish	4.0
Sea cucumbers	2.2	Scorpionfish	4.0
Blue crab	1.4	Small reef fish	3.0
Barred pargo	1.2	Small demersal fish	3.0
Snails	1.0	Crabs and lobsters	2.0
Penaeid shrimp	0.9		
Amarillo snapper	0.8	**Pelagic groups**	**Multiplier**
Pacific angel shark	0.7	Small pelagics	1.00
Large pelagic sharks	0.7	Hake	0.55
Totoaba	0.5	Large pelagics	0.12
Bivalves	0.35	Mackerel	0.04

[23] L. E. Calderón-Aguilera, CICESE, Ensenada, BC, Mexico. Pers. commun., 19 September 2008.

Fulton et al. 2004a) including physical constants (e.g., hydrodynamic parameters), porosity of sediment, bioirrigation parameters, depth of microbial activity in sediment, erosion rates, base nitrification and denitrification rates (modified dynamically within the model based on the standing benthic biomass values and levels of benthic activity), light adaptation rates, light intensity, and base surface stress values. The following section describes parameterization of the CDF file specific to the upper Gulf of California.

Physical Characteristic and Nutrient Depth Profiles

Depth profiles for temperature and salinity were based on data found in four articles: Pegau et al. (1999), Gaxiola-Castro et al. (1999), Alvarez-Borrego and Gaxiola-Castro (1988), and Hernandez-Becerril (1987). Data in Pegau et al. (1999), Gaxiola-Castro et al. (1999), and Hernandez-Becerril (1987) were regenerated from figures using a graphics tracing program (Martell unpubl. data). Where sampling occurred within the study area, we applied those depth profiles directly to the corresponding Atlantis polygons. The remaining polygons were categorized as either shelf or oceanic areas, and average values from the four source articles were computed for these two area types. The value for shelf areas was computed as an average of all sampling stations occurring inshore (i.e., less than approximately 80 m depth). The value for oceanic areas was computed as the average of all sampling stations occurring in the central gulf (i.e., in areas greater than 80 m depth). None of the source papers sampled deeper than 500 m, so for temperature, we extrapolated to greater depth categories by fitting a trend line of the form $Y = aX^b$ through the shallow data points. We assumed that salinity at depths greater than 500 m remained constant at the 500 m levels.

Nutrient depth profiles were available in Gaxiola-Castro et al. (1999) for dissolved oxygen, nitrates, and chlorophyll *a*, while Alvarez-Borrego and Gaxiola-Castro (1988) and Hernandez-Becerril (1987) provided depth profiles for nitrates and chlorophyll *a*. Alvarez-Borrego and Gaxiola-Castro (1988) provided silicate depth profiles. Concentrations of these nutrients were averaged at each depth class. Although samples were taken at various times of the year, nutrient levels in the northern gulf show little seasonal fluctuation, possibly because the constantly eroding sediment of the Colorado River depositional basin provides a steady influx of new material, along with agricultural runoff (Brusca et al. 2005). No ammonium depth profile could be found for the northern gulf, but average surface concentrations in the southern Gulf of California are approximately 2 μM (Bustos-Serrano and Castro-Valdez 2005). We assumed the concentration decreases linearly with depth and falls to a minimum of 10% at 500 m depth.

Eddy Strength

Eddy strength parameters are relative scaling terms that reflect increased primary production in polygons resulting from oceanic convergence, nutrient upwelling, or both. Ideally, the parameter should be set proportionately to the coefficient of variation in sea surface height, measured temporally or spatially. We set placeholders for these parameters approximately to reflect the persistent gyre in the northern gulf, north of the Midriff Islands (Beier 1997, Lavín et al. 1997); this area was given relatively large eddy strength. Smaller eddy strength was set in polygons lining the eastern shore of the gulf to represent the upwelling that occurs there

(Santamaría-del-Angel et al. 1994, Gaxiola-Castro et al. 1999). Eddy strength per polygon is reported in Table 5.

Area Cover

Area cover ratios by polygon for flat and soft bottoms were based on sediment maps developed for the PANGAS project (Cudney-Bueno et al. 2007). Area cover of canyon habitat was set manually, assuming that canyon area mainly occurs in the Canal de Ballenas and to a lesser extent in the Archipelago de San Lorenzo and in the deep area north of Isla Angel de la Guarda. Area cover ratio for rock bottoms, seagrass, and macroalgae were based on Morzaria-Luna and Turk-Boyer (2009). Area cover per polygon is reported in Table 5.

Dynamics File (PRM)

MUM and Clearance

Atlantis parameter MUM (C programming variable, *g* in equation 7) is the maximum absolute daily production in units mg N • d^{-1} • $individual^{-1}$ that a predator realizes when the encounter rate with prey is high. It represents the maximum consumption rate (i.e., G_{MAX}, the asymptote of the Holling type 2 function response) multiplied by an assimilation efficiency (E in equation 7) as follows

$$g = G_{MAX} \cdot E \tag{20}$$

We estimate G_{MAX}, applying the weight-consumption relationship from Hanson et al. (1997)

$$G_{MAX} = CA \cdot Weight^{CB} \tag{21}$$

We used weight estimates from von Bertalanffy curves (structural + reserve nitrogen) to obtain maximum consumption for an average individual and we generalized the constants across functional groups, setting CA = 0.3 and CB = 0.7 after Horne et al. (2009). We considered growth efficiency to be 10% (Pauly and Christensen 1995). MUM values used in the northern Gulf of California model are provided in Table A-6 (vertebrates) and Table 11 (invertebrates).

Clearance (C in equation 7) is a measure of feeding efficiency when prey is scarce; it reflects the slope of the predator-prey functional response near the origin. As programmed in Atlantis, clearance is analogous conceptually to the volume of water filtered by filter feeders, although this may be generalized to swept-volume for other predators; its units are therefore m^3 • mg N^{-1} • d^{-1}. Initial values were set at one-tenth of MUM after Horne et al. (2009). Clearance values used in the northern Gulf of California model are provided in Table A-7 (vertebrates) and Table 11 (invertebrates).

Gape Size

Atlantis modifies the predator/prey interactions predicted by the functional response to take predator gape into account. Here, gape size parameters for fish were set based on morphometric measurements taken for the Atlantis Gulf of California project (this model and

Table 11. Growth rate (MUM) (g; mg N • d^{-1} • $individual^{-1}$) and ingestion rate (clearance) (C; m^3 • mg N^{-1} • d^{-1}) for invertebrates. See Table A-6 for vertebrate data.

Group	MUM (g)	Clearance (C)
ZG	0.218	0.100
ZL	20.000	0.200
ZM	8.000	0.100
ZS	32.800	0.200
BFS	0.100	0.030
BFD	2.000	0.040
BFF	0.033	0.015
BD	0.010	0.010
BC	0.005	0.012
BG	0.060	0.018
BMS	0.500	0.100
BML	2.000	0.200
BMD	0.900	0.010
BO	0.500	0.003
PB	0.500	0.100
BB	2.000	0.100
CEP	0.200	0.100
jCEP	0.020	0.100
PWN	0.093	0.200
jPWN	0.030	0.100
MA	0.400	
PL	0.022	
PS	2.000	
SG	0.900	
PL	1.500	
PS	1.500	
MA	1.200	
SG	1.200	
MB	0.300	

document). Specimens collected for diet content analysis were measured according to the protocol in Appendix C. Some 374 individual fish had body length and gape size measurements, representing 15 Atlantis functional groups. Figure 11 shows the relationships for 8 groups possessing at least 10 observations.

A recent modification to the Atlantis software made for this project allows the user to input restrictions on prey size as a function of predator gape size for all vertebrate consumer groups and several invertebrates. Previously, gape related feeding limitations were defined by generic feeding guilds, to which predator functional groups could be assigned; predator fish groups could assume one of five guild types, while an additional six types were available to represent nonfish guilds. The new version of the code (December 2008) allows gape size feeding restrictions for each predator functional group to be set independently, so that we could incorporate the detailed biometric data presented here. Upper and lower limits on prey body weight were set as a fraction of predator body weight. Within the eligible weight range, prey were entirely available, and outside of the eligible range, they were unavailable.

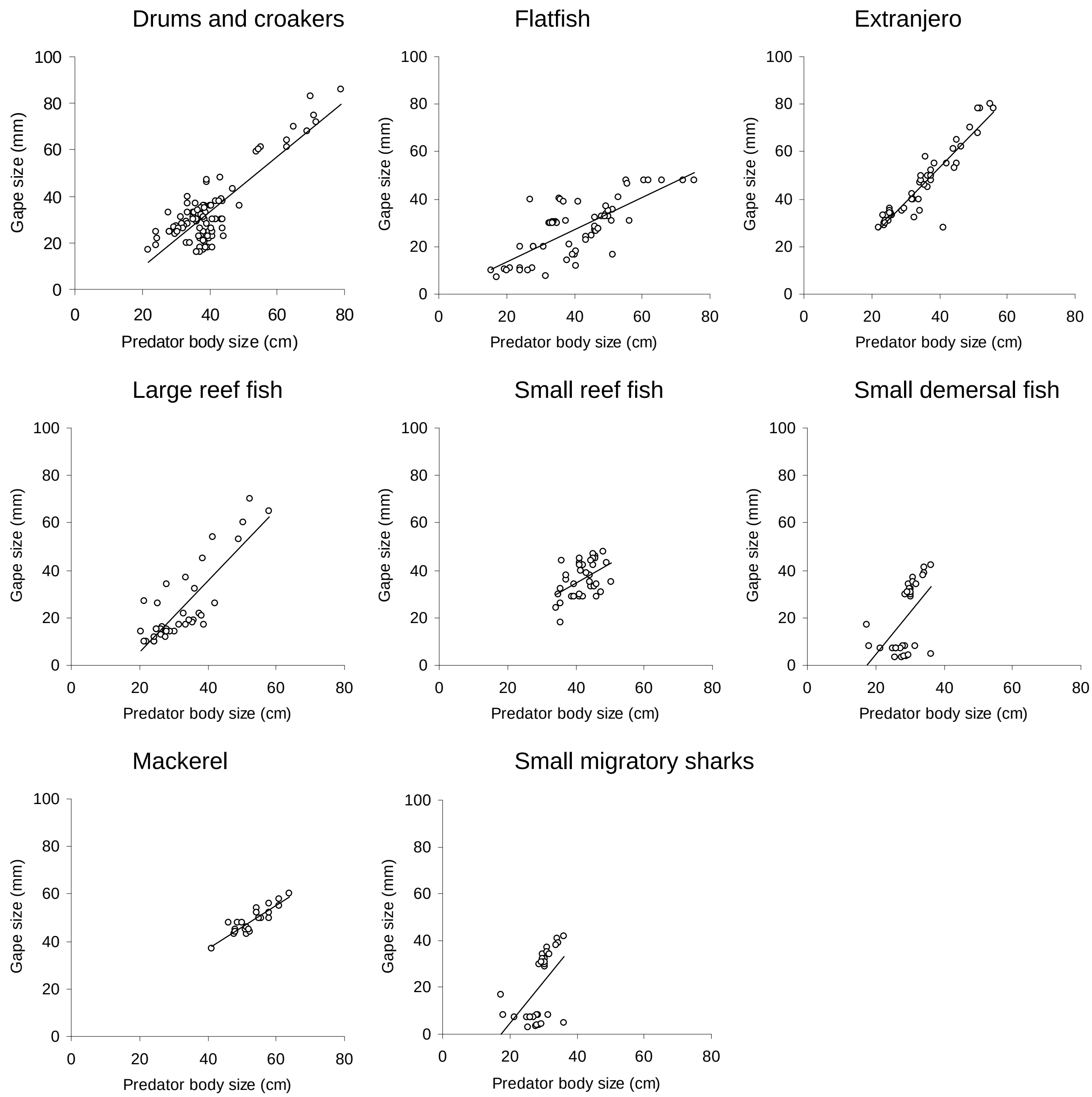


Figure 11. Fish gape size versus length from sampling. Groups have at least 10 observations. R^2: drums and croakers (0.72), flatfish (0.56), extranjero (0.86), large reef fish (0.70), small reef fish (0.22), small demersal fish (0.28), mackerel (0.79), and small migratory sharks (0.37).

We assumed no lower limit on the size of prey available to predators; Table 12 presents the upper limit. The upper limit was calculated using the length-weight relationship in equation 12, where prey body length was assumed 2.5 times greater than the limiting physical dimension, represented here by predator gape. The length-weight parameters used to translate prey body length to body weight were based on the samples collected here; A and B parameters are taken as the average for all sampled groups (see length-weight plots in Figure B-1 and Figure B-2 and parameters in Table B-1), weighted by the number of samples available. We therefore assumed that fish abundant in the ecosystem were sampled more frequently. For other functional groups

Table 12. Morphometric data for fish sampled in the Gulf of California. Maximum prey ratio represents the ratio of predator mean weight (measured) to maximum ingestible prey weight (estimated). Prey weight was calculated based on maximum prey body length, where maximum prey body length was assumed 2.5 times greater than the limiting physical dimension, set by predator gape. Length-weight parameters for prey fish were assumed similar to sampled predators, and calculated as average A and B values weighted by the number of samples per functional group.

Group	No.	Mean length (mm)	SD	Mean weight (g)	SD	Mean gape (mm)	SD	Estimated max. prey weight (g)	Max prey ratio
Drums and croakers	99	398	10.5	722	651	33.0	14.8	220	0.304
Flatfish	62	416	14.5	968	1,158	30.6	26.6	185	0.191
Extranjero	48	348	9.6	627	598	45.7	15.1	463	0.739
Large reef fish	39	321	9.1	780	631	24.3	16.4	110	0.141
Small reef fish	36	421	4.3	844	274	36.3	7.4	274	0.324
Small demersal fish	32	290	4.3	514	190	20.4	14.4	74	0.143
Mackerel	23	528	5.5	829	283	48.6	5.6	531	0.641
Herbivorous fish	11	346	0.9	398	39	19.2	3.0	64	0.161
Small migratory sharks	10	660	3.5	935	109	26.1	2.1	129	0.138
Leopard grouper	6	742	9.1	5,350	1,310	91.7	9.4	2,259	0.422
Gulf coney	3	210	4.4	146	65	20.7	16.1	76	0.520
Gulf grouper	2	946	57.1	16,888	15,113	130.5	77.1	5,053	0.299
Barred pargo	1	791	—	10,900	—	108.0	—	—	—
Groupers and snappers	1	331	—	575	—	4.4	—	—	—
Large pelagics	1	789	—	3,925	—	69.0	—	—	—
Total	374								

not sampled, we assumed the following maximum ingestible prey weight to predator weight ratios: sharks and birds (biters) 3, turtles 0.2, mammals 0.1, carnivorous invertebrates 0.5, and planktivorous invertebrates 0.2.

Box Geometry Model File

The spatial map for the Atlantis model consists of 66 polygons, 193 faces, and 178 unique vertices (Figure 12). The design of the map considers four major factors. First, it incorporates locations of marine reserves including the Upper Gulf of California and Colorado River Delta Biosphere Reserve (nuclear and buffer zones), the Bahia de Los Angeles Canal de Ballenas y Salsipuedes Biosphere Reserve around the waters of the Isla Angel de la Guarda, the Parque Nacional Marino Archipelago de San Lorenzo to the south of Isla Angel de la Guarda, and the Isla San Pedro Martir Biosphere Reserve near Isla Tiburón.

Second, the map contours follow the bathymetry at the 25, 80, 150, 500, and 1,000 m isobaths (Figure 13). These depth ranges were chosen to divide the study area into discrete regions in which various gear types operate, according to expert opinion. Shore gill net (chinchorro), air-supplied dive fisheries (hooka), and crab traps operate approximately to 25 m maximum depth. Longlines (cimbra) may operate in waters as deep as 150 m, but more often fish in the 60–80 m range. We considered that shrimp trawls operated by large (15–20 m) diesel

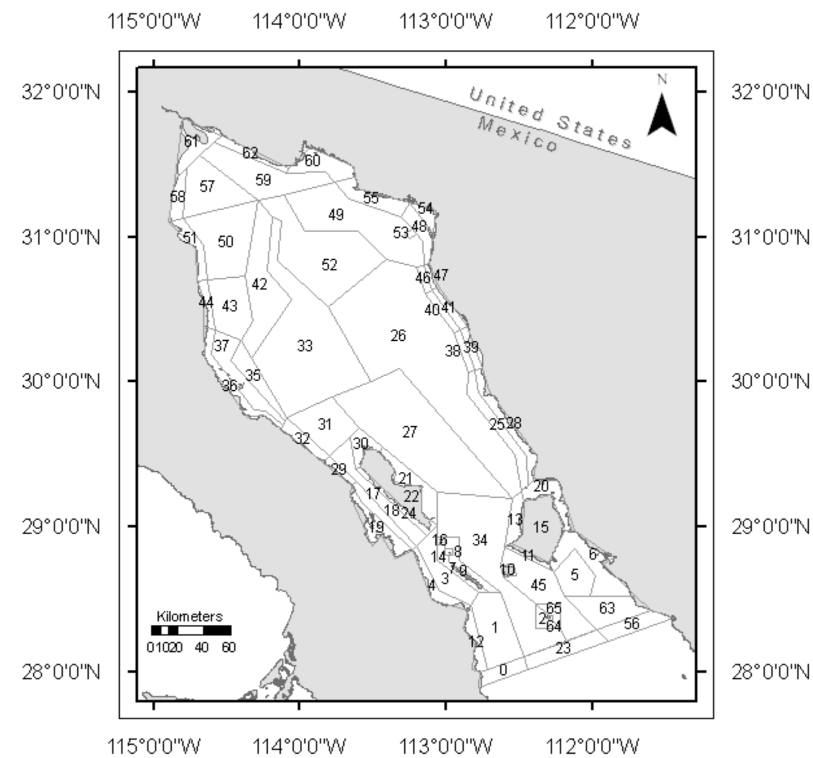


Figure 12. Atlantis polygons with box numbers.

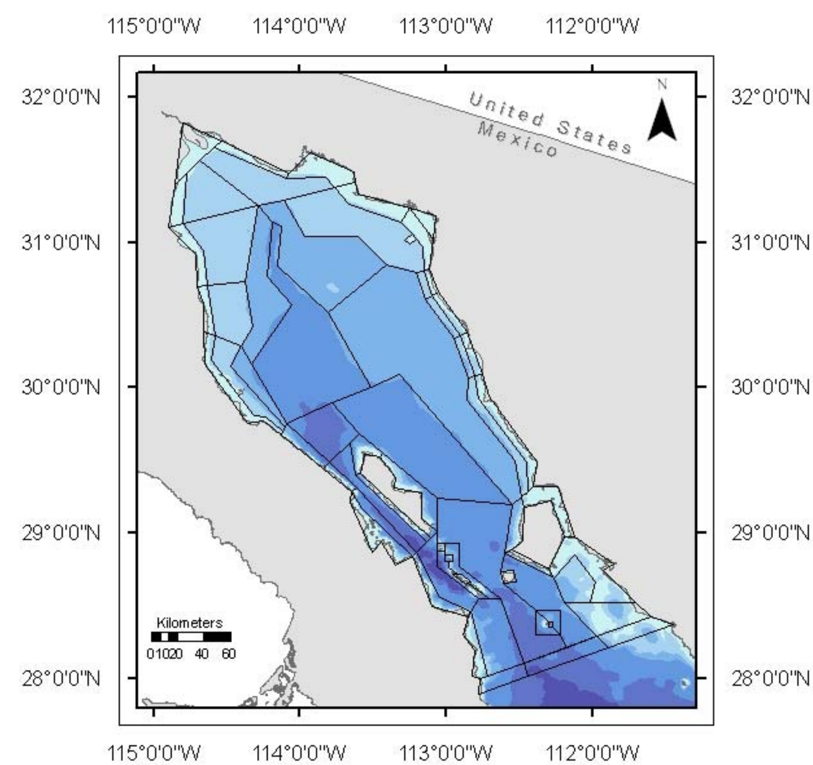


Figure 13. Bathymetry with Atlantis polygons overlayed. Shown are 25, 80, 150, 500 and 1,000 m isobaths.

boats using a hydraulic hauling mechanism can fish as deep as 500 m. Areas deeper than the 500 m contour were assumed to be exclusive pelagic fishery areas.

Third, the contours set by depth are divided transversely according to the location of fishing ports (Figure 1). Traditional fishing areas surround each of these ports where local small-scale fishing operations, such as those pursued by pangas, typically have exclusive access. The sea areas immediately outside of each fishing port tend to be fished by a small number of cooperatives or companies in the case of demersal and inshore pelagic fisheries, so this map design may facilitate analysis of bottom-up harvest controls or incentives. Fishing statistics may also be collected at the port level, while estimates of unreported catch can be matched to the cooperatives and companies fishing these areas. Finally, the areas represented correspond roughly to the areas of fishing use described by Cudney-Bueno and Turk-Boyer (1998).

Oceanographic Forcing Using ROMS Model

A ROMS was employed using Atlantis' model coupling capabilities to provide hydrodynamic forcing information, ocean temperature, and salinity fluxes. These influences affect nutrient transport and animal metabolism in the biological model (Fulton 2001, Fulton et al. 2004a). The ROMS model for the northern Gulf of California was developed by Dr. Alejandro Pares-Sierra, Dr. Miguel Lavin, and others in the Department of Physical Oceanography at CICESE (Ensenada, Mexico). Data from the ROMS model was integrated at 12-hour time steps across horizontal and vertical polygon boundaries. The data series was entered into the 1985 Atlantis model as a precalculated time series of rate parameters extending from 1985 to 2008. For simulations using the 2008 Atlantis model, the same series was used; thus we assumed that future water movement, ocean temperature, and salinity will be similar in magnitude and variability over coming decades. For projections lasting longer than the ROMS time series, the data was looped.

ROMS is a free surface, terrain-following ocean model, which solves incompressible hydrostatic primitive equations with potential temperature, salinity, and an equation of state (Mateos et al. 2009). The oceanic model was based on the S-coordinate Rutgers University Model also known as SCRUM, described by Song and Haidvogel (1994). It has been developed and enhanced by the University of California Los Angeles. Vertical boundary conditions employed are wind force and heat fluxes on the surface and quadratic friction on the bottom. Horizontal boundary conditions employed are temperature, salinity, and speed through lateral boundaries. For computational efficiency, ROMS resolves moment equations using a divided time step (barotropic and baroclinic) that requires special treatment and coupling between the barotropic (long time steps) and baroclinic (short time steps) modes. The open boundary conditions and vertically integrated moment equations are calculated through finite barotropic time steps in each baroclinic timestep. Both the vertical and horizontal moment equations adopt a second order approximation with finite differences. For implementation of the model in the northern Gulf of California, we used a nested design with a submodel for the gulf, as shown in Figure 14 (Pares-Sierra unpubl. data).

The parent grid has a horizontal resolution of 3.5 km and a vertical resolution level of 20 levels (evaluated over 128 x 256 x 20 grid points) distributed between 0 and 2,800 m approximately. We used bathymetry by Smith and Sandwell (1997) with 2 minute resolution.

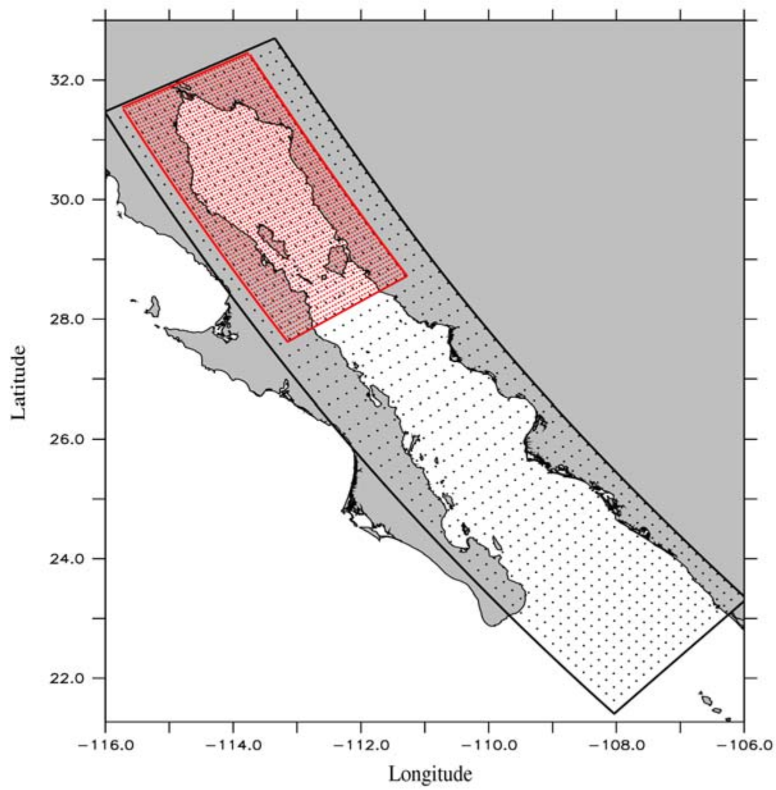


Figure 14. Spatial domain and grid resolution of the Gulf of California ROMS model. The inner grid shows the area employed in the northern Gulf of California Atlantis model (1 km^2 resolution), the outer grid covers a larger area (3.5 km^2 resolution).

The parent grid was forced laterally by the results of a global simple ocean data assimilation (SODA) model. SODA is a model that assimilates and constantly corrects the output from a global circulation model (Parallel Ocean Program numerics, Smith et al. 1992). It uses satellite data and current and historical hydrographic data. The SODA database has a spatial resolution of 0.5° x 0.5° in a vertical resolution level of 40 levels from 1958 to 2007. The surface model is forced by winds from the North American Regional Reanalysis (NARR) and by heat fluxes from the Comprehensive Ocean-Atmosphere Data Set (COADS) reported by DaSilva (1994). The surface temperature is gently relaxed towards the Advanced Very High Resolution Radiometer satellite temperature. An important component for the region's dynamics is tidal variation, which is included at the gulf entrance using the output of the global tidal model (TPXO.7) developed by Oregon State University (Egbert and Erofeeva 2002).

The northern gulf model has a resolution of approximately 1 km and is embedded in the model previously described, with lateral forcing resulting from the parent model for the complete gulf (evaluated over 203 x 359 x 20 grid points). On the surface, just as in the parent model, the model is forced with wind data from NARR and heat fluxes from COADS. The bathymetry used was from a global digital elevation model (ETOPO2) enhanced with data from CICESE's historical data. Figure 15 shows an example from surface temperature. We used data from this model to calculate mean transport, temperature, and salinity for each of the Atlantis polygons (Figure 16).

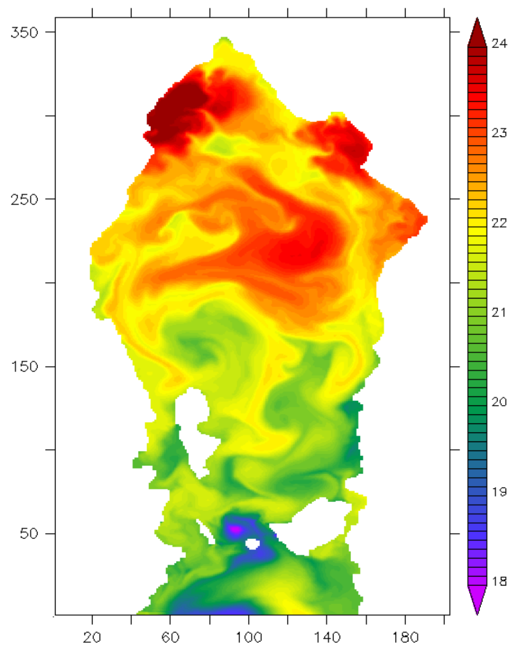


Figure 15. Sea surface temperature example for northern Gulf of California ROMS model. Color scale shows temperature (°C). X and y axes show grid point resolution.

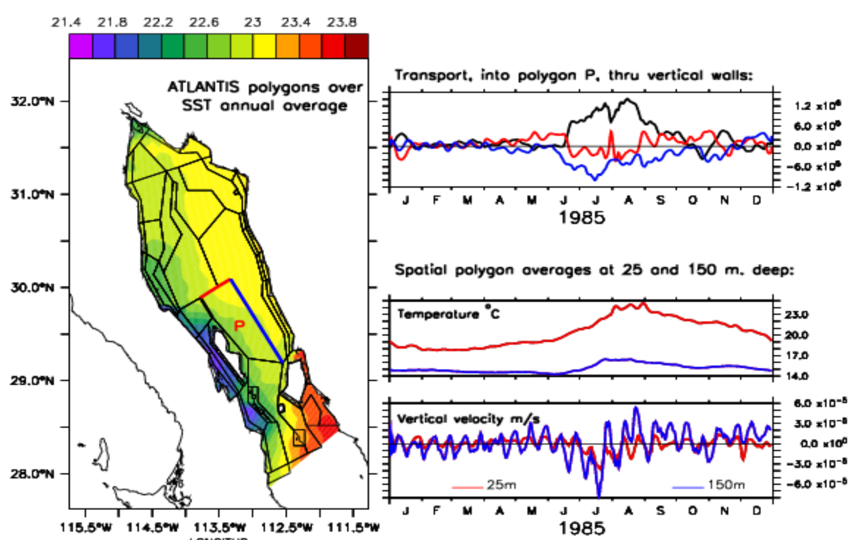


Figure 16. Annual mean water transport, temperature, and salinity example (1985) for the northern Gulf of California ROMS model.

1985 Historical Model

To tune dynamic parameters in an ecosystem simulation model, it is necessary to compare the predicted dynamics with historical time series of catch and relative abundance. In the case of a present-day model, such as our 2008 Atlantis model, there is no time series data available extending into the future. Therefore, we adopted an approach in which we tune dynamics of a historic model to available data, then transfer the dynamic parameters to the present-day model assuming stationarity in feeding behavior and life history parameters of organisms (Ainsworth et al. 2008b). We chose as a starting point for the historic model the year 1985 because we have the most complete record of time series catch and relative abundance data from this point. In addition, it is the earliest available year provided by the ROMS model. This section details the development of the historic 1985 model for the northern gulf, the development of time series data, and the tuning process.

For model initialization, species biomasses in 1985 were estimated relative to the 2008 model (2008 model parameterization is described above in the 2008 Model Biomass Initialization subsection). Scaling factors were used to adjust the 2008 values to reflect past ecosystem conditions. The scaling factor per functional group was developed based on two main methods. The first method was to adapt the series of relative abundance developed from a fuzzy logic analysis of fisher interview information (Ainsworth in press). The second was to base the change in relative abundance on available CPUE series, developed here. Biomasses for 1985 are in Table B-2.

In the case of CPUE, trends were developed based on catch statistics from the Mexican government (Carta Nacional Pesquera in Diario Oficial de la Federación 2004b, 2006b; CONAPESCA 2009), unpublished statistics (Valdéz-Ornelas and Torreblanca unpubl. data), port-level surveys (Perez-Valencia unpubl. data), fishery log books (Torre and Rojo unpubl. data), and other sources listed in Table 9.

Effort trends were estimated for the number of pangas operating in the northern gulf and applied to several functional groups whose primary fishery utilizes these vessels (Galindo-Bect 2003). Other effort series were located for lobster (Vega-Velásquez 2006), urchin (INAPESCA 2006a), small pelagics (Nevárez-Martínez et al. 2006), groupers (Arreguín-Sánchez et al. 2006), totoaba (Lercari and Chavez 2007), and shrimp (Galindo-Bect 2003). As a last resort, effort was based on the average human population growth rate in two Sonoran cities, Puerto Peñasco and San Felipe (Sonora 2008a, 2008b). In several cases, linear extrapolations were used to fill data gaps between years. Catch in 1985 was set to match our time series in Figure B-11 and Figure B-12. Sources for effort data are provided in Table 9. All other parameters were shared between the 1985 and 2008 models. In distributing biomass among polygons, the same relative spatial pattern was used for the 1985 model as was used for the 2008 model (Figure B-5 through Figure B-9), but the absolute quantity of biomass varied.

Model Tuning and Diagnostics

The slow run-time of Atlantis prohibits any automated estimation of model parameters. Instead, the procedure to adjust input parameters that has been followed in previous successful implementations of Atlantis (Fulton et al. 2004a, Fulton et al. 2004b, Brand et al. 2007, Horne et al. 2009) is an iterative process in which state and rate parameters are adjusted in order to generate realistic system behavior and fit model predictions qualitatively to observations. The methods and goals used by the modeler are subjective, but the overall strategy employed has so far been consistent in all Australian and U.S. models constructed to date.

Modelers adjust the most influential parameters in Atlantis (Fulton 2001): recruitment variables, prey availabilities, clearance (i.e., predator consumption) and MUM (growth), weight of recruits, and linear and quadratic mortality. Recruiment variables used in the Gulf of California models are Beverton-Holt alpha and beta values for fecund teleost fish and invertebrates, and fixed recruitment per adult female for elasmobranchs, mammals, birds, and reptiles. These parameters are adjusted until extinctions no longer occur under baseline fishing conditions and vertebrate numbers, body weights, and biomasses reach a stable equilibrium with reasonable values.

A simulation without fishing, beginning from an exploited ecosystem base such as the Gulf of California in 1985 or 2008, should result in a slow increase in the biomass and abundance of exploited functional groups to some stable equilibrium level (unexploited biomass, B_0, or numbers, N_0). The prey groups of those predators should respond with a concomitant decrease in biomass or abundance. Under historical reconstruction scenarios, in which a past model such as the 1985 Gulf of California model is driven forward by time series of historical catch and oceanography, the observed species abundance trends, as from sampling or independent stock assessment models, should be re-created. For individual weight, a common rule of thumb is that reserve and structural nitrogen per individual should remain within the range of 0.5 to 1.5 times the intial values (i.e., the static equilibrium rests in that range) unless the system has been heavily perturbed. Results from tuning the 1985 and 2008 models are presented in the following section.

Results

No Fishing Scenario (1985 to 2008)

Biomass and Abundance

Results from the Gulf of California 1985 simulation with no fishing are presented in Appendix D, Figure D-1 through Figure D-4 (biomass) and Figure D-5 through Figure D-7 (numbers); model behavior generally conforms to the diagnostic guidelines outlined in the above section. Heavily exploited functional groups (e.g., gulf coney, extranjero, leopard grouper, gulf grouper, amarillo snapper, barred pargo, groupers and snappers, large reef fish, mojarra, mackerel) increase in biomass to a stable equilibrium (B_0) upon release from fishing pressure (Figure 17). The result is less obvious in some highly aggregrated functional groups in which only a fraction of species are heavily exploited (e.g., chano are contained in the aggregate group drums and croakers). Responding to this increase in predator biomass, the prey base of the ecosystem is eroded (e.g., small demersal fish, small reef fish). Groups not heavily exploited (e.g., macroalgae, sessile invertebrates) maintain an equilibrium biomass close to their initial values. Seasonality is also evident in the biomass plots; for example, large phytoplankton and small phytoplankton fluctuate according to availability of light and nutrients defined by the ROMS oceanographic inputs, while zooplankton shows an appropriate first-order reaction.

A few irregularities persist in the 1985 to 2008 simulation. For example, carrion detritus is too quickly degraded into the labile and refractory pools. The saw-tooth pattern in the small migratory shark biomass profile is due to excessive mortality occurring in adult age-classes; the biomass is composed mainly of juveniles, so seasonal recruitment pulses seem exaggerated. Some invertebrate groups are also prone to decline in biomass under any permutation (e.g., herbivorous echinoderms, infaunal and epifaunal meiobenthos). Brand et al. (2007) and Horne et al. (2009) faced similar difficulties with invertebrates; this may reflect insufficient optimal habitat defined in the model.

The apparent decline in sea birds is the result of an unresolved data read-in problem in Atlantis, as the actual initialization biomass used (874.3 mt in both the 1985 and 2008 models, see Seabirds under Functional Group Descriptions subsection above) is far less than what is being reported in the log.txt output file (≈15,000 mt). The error may be related to the fact that some polygons begin with zero individuals. A similar problem was encountered with orcas and mysticeti, but could be corrected in the latter. Interestingly, the stable biomass of sea birds predicted by Atlantis is close to our calculated value. Finally, numbers in the adult stanzas of some long-lived vertebrate groups (i.e., oceanic sea turtles, reef associated turtles, odontocetae, mysticeti) decline slowly despite an abundance of immature individuals. These species are not fished under this scenario, have few natural predators, and are not starving (Figure D-10). Additional troubleshooting is required to identify the source of adult mortality.

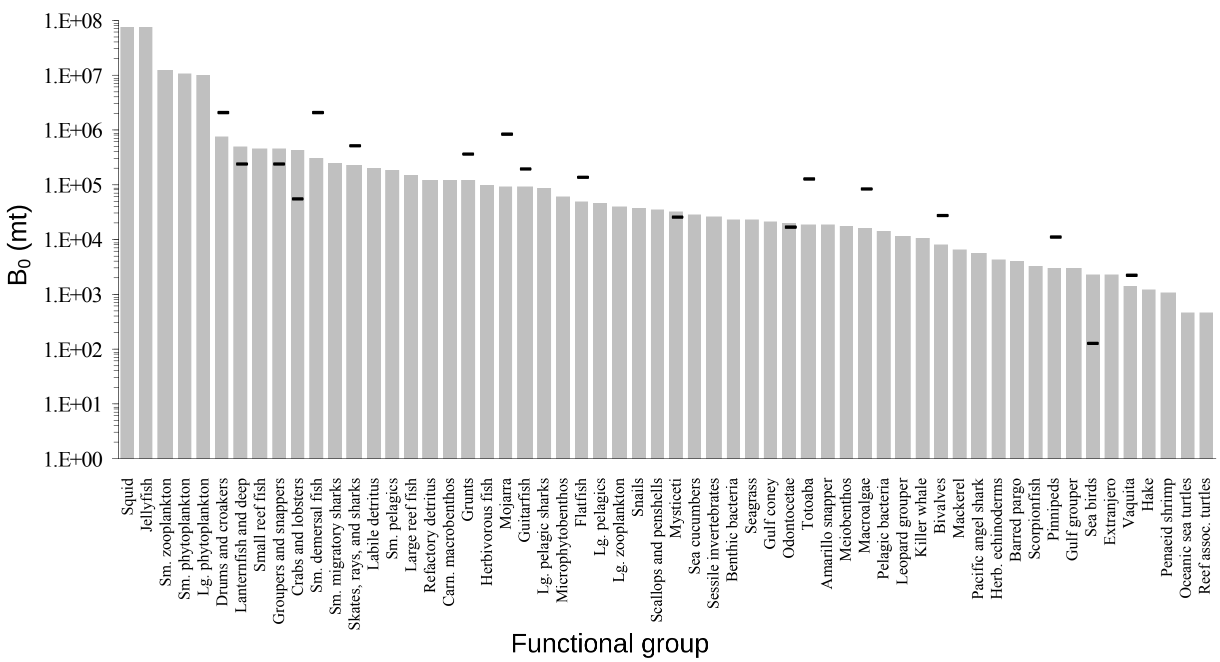


Figure 17. Unexploited biomass (B_0) predicted by the tuned 1985 model (bars); 1950 biomass estimated by Lozano 2006 (dashes).

Individual Weight-at-age

Individual weight at age (structural and reserve nitrogen) remains within an acceptable range for most functional groups and age-classes. A stable equilibrium forms for most groups with body weights ranging from 0.5 and 1.5 times initial values (Figure 18 and Figure D-8 through Figure D-13). A decline in reserve nitrogen (which represents muscle, fat, gonads, and other soft-body tissue) beyond this range is symptomatic of starvation, which can be caused by low consumption rates (i.e., defined in clearance or availability parameters), low prey abundance, or too restrictive gape limitation settings. An increase in reserve nitrogen beyond this range indicates overconsumption. Structural nitrogen (which represents bone and hard parts) is less sensitive to the effects of starvation. The drums and croakers, flatfish, and seabird groups suffer slight starvation, while herbivorous fish, mackerel, and sea turtles exhibit moderate overconsumption. Most functional groups experience a slight spreading out of weights at age, meaning that the stable weights of young age-classes are generally less than those inputted in initial conditions, while the stable weights of older age-classes is greater than initial values. This can be seen in Figure 18. Further tuning of individual growth rates used in the initial conditions is required to resolve this problem.

Historical Reconstruction (1985 to 2008)

Reconstructing the recent history of the northern Gulf of California is both a diagnostic procedure useful for tuning the 1985 model and a learning exercise that helps us understand what forces have shaped the ecosystem. The historical reconstruction is presented in Figure D-14 through Figure D-17. We previously estimated what quantity of removals was necessary to

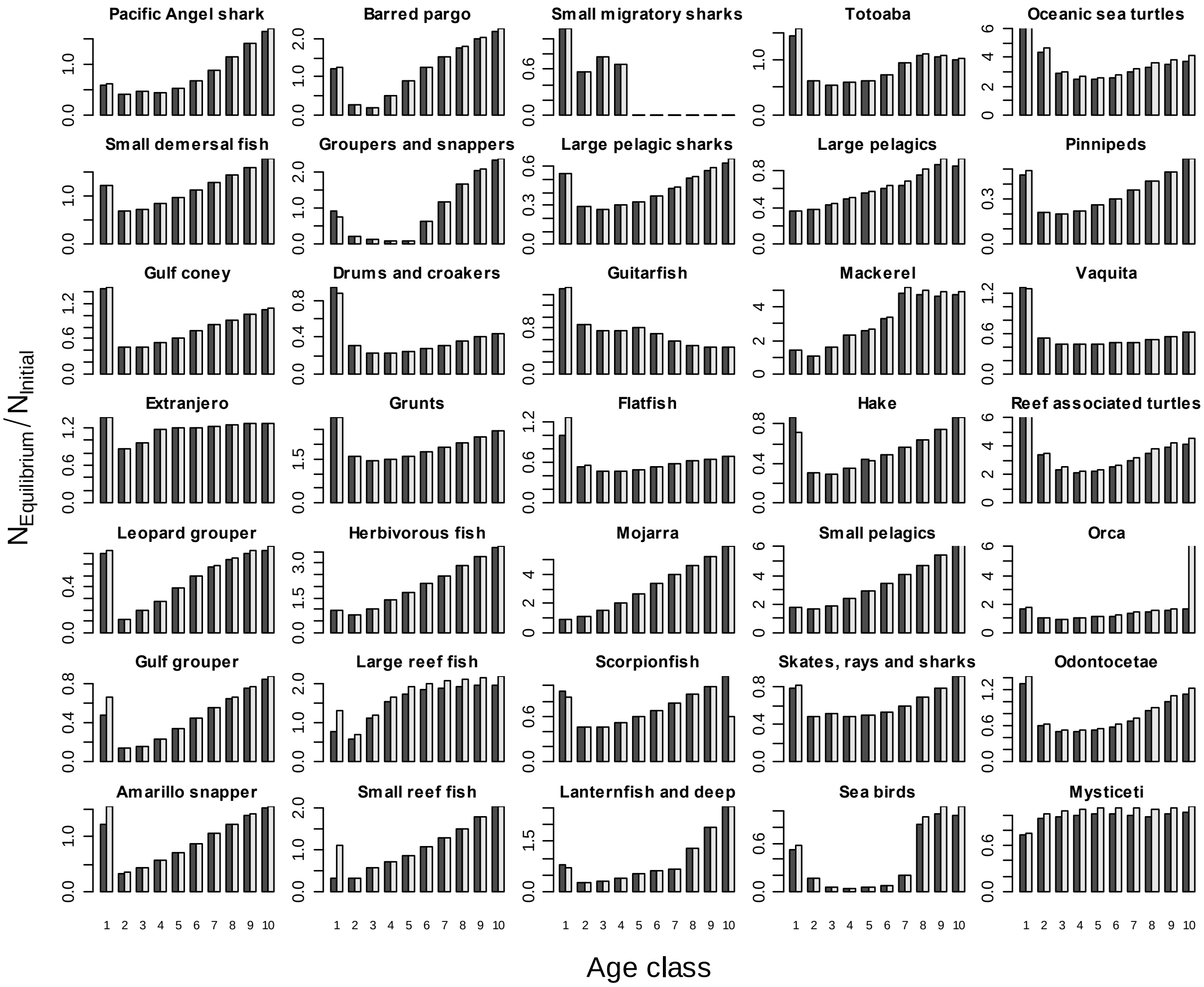


Figure 18. Reserve nitrogen (black bars) and structural nitrogen (gray bars) at the end of the no-fishing scenario (1985 to 2008) relative to initial conditions in the 1985 model.

produce the observed declines in biomass in exploited groups (Table 10), and found that the quantity of recorded catch had to be multiplied by several times to account for unreported catch and discards. Driving the 1985 model foward 23 years under the revised catch estimates to the year 2008, and using the historical oceanographic forcing from the ROMS model, the 1985 model can be projected forward for 23 years to resemble the 2008 ecosystem condition. The following results show that the Atlantis model performs well in this regard.

Most functional groups (76%) fall within one order of magnitude of 2008 biomass values (Figure 19), while 95% fall within two orders of magnitude. Groups that show the largest discrepancy, totoaba and vaquita, were predicted by the historical reconstruction to have recovered by the present-day. In actuality, biomasses of both groups have remained low in the northern Gulf of California since the mid-1980s. However, we have assumed a very low incidental catch rate for totoaba and zero catches for vaquita between 1985 and 2008. The model therefore suggests that some additional source of mortality may have been present for these animals over this window, from fisheries or other sources. However, at an estimated 10.3 and

3.3 mt of standing stock biomass respectively in 2008, any significant growth of totoaba or vaquita stocks in the historical reconstruction will seem large by comparison.

Microphytobenthos and jellyfish biomasses were also overestimated by the historical reconstruction. In the case of jellyfish, the behavior of the group still needs some fine tuning, as they are prone to increase under most model permutations. We also neglected to include a small exploratory fishery that began in 2005 targeting cannonball jellyfish (*Stomolophus meleagris*) near Bahia Kino, although effects of this are likely insignificant as the fishery takes a relatively small amount of catch, between 1,000 and 6,000 mt per year (Sonora 2008). The increase in microphytobenthos occurs entirely in the last few years of the historical reconstruction scenario (Figure D-16 and Figure D-17) and indicates instability in this group. However, behavior of this group is highly sensitive to input conditions and under some permutations they behave reasonably.

Large zooplankton, bivalves, and meiobenthos decrease during the simulation more than expected. Large zooplankton and meiobenthos continue to be problematic groups; their biomasses decrease disastrously during both the historical reconstruction and the no-fishing scenario (Figure D-16 through Figure D-17), suggesting the problem is not related to fishery effects but to over predation, group productivity, or both. The former is more likely in the case of meiobenthos, as they increase in biomass substantially when predators are removed from the system (Figure D-18 through Figure D-20). Declines were consistent for both groups over a wide range of productivity values. This abberant behavior remains unresolved. Fortunately, other basal species perform well, so the misrepresentation of these groups should not compromise overall model performance.

Despite the results in Figure 19, hake responded quite reasonably to fishing pressure in the historical reconstruction scenario (e.g., Figure D-16 and Figure D-17). The discrepancy is not due to problem dynamics but to inappropriate input parameters: we used a relatively low biomass value in the 1985 model, which was based on the relative CPUE between periods (Table B-2). There has been a 20-fold increase in CPUE between these periods (see subsection 1985 historical model). This likely does not reflect a real change in biomass density, but an increase in the catching efficiency by fishermen. For a discussion on the difficulties of using CPUE as an indicator of relative abundance, refer to Hilborn and Walters (1992). Revisions to the 1985 model should include an increased estimate of hake biomass.

Forward Projections from 2008

Spatial Dynamics

Whereas Figure B-5 through Figure B-9 show the absolute distribution of biomass per polygon used to initialize the 2008 model (as well as the relative distributions in the 1985 model), these distributions are expected to change dynamically during simulations. Flux rates between cells, which reflect the combined effects of advection (for plankton groups), random diffusion, foraging, and seasonal migrations, will be futher affected by organisms' tendency to occupy suitable habitat, maximize feeding, and minimize predation risk. Under simulation using constant fishing rates per polygon, we would expect the ecosystem represented in Atlantis to arrive at some stable spatial equilibrium state, except for the influence of the hydrodynamic

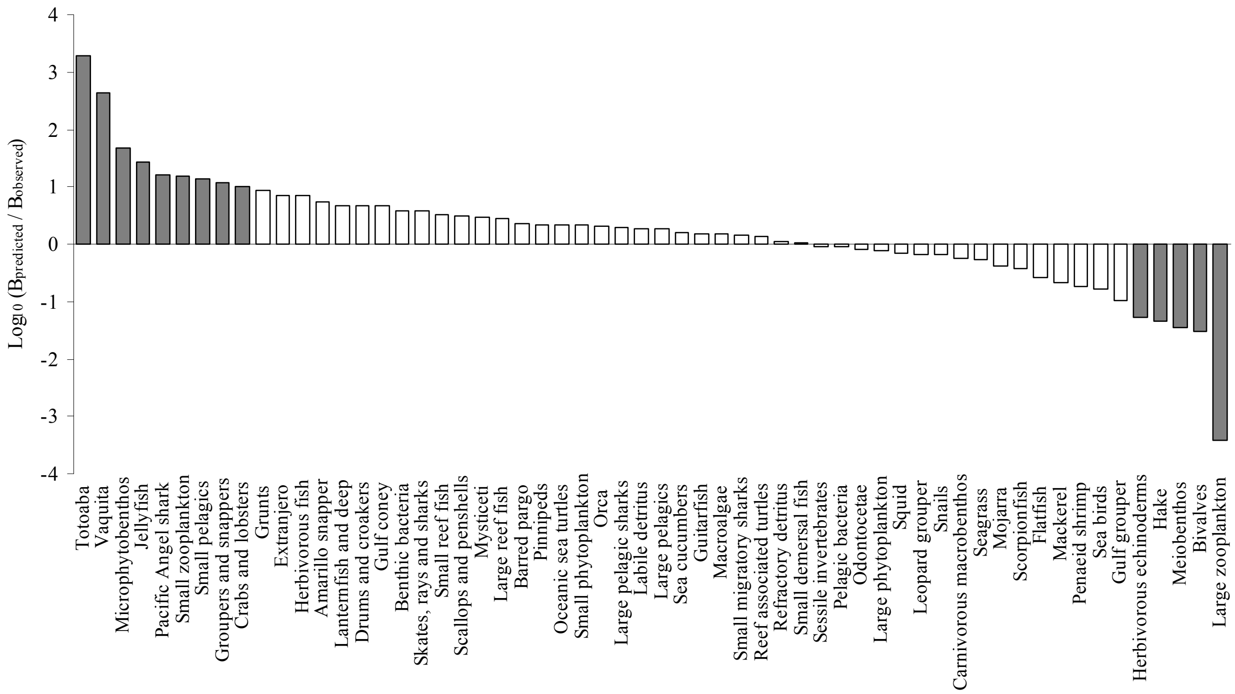


Figure 19. Predicted versus observed biomass in 2008. Under an historical reconstruction scenario, the 1985 model is driven forward 23 years to 2008. The resulting species biomass vector (predicted) is compared to biomasses used in the 2008 model from surveys and other sources (observed). For 76% of functional groups (white bars) the predicted biomasses are within an order of magnitude of the expected values; 95% are within two orders of magnitude. Largest discrepancies occur in totoaba and vaquita, which are predicted to have recovered by 2008 (historical reconstruction assumed minimal catch in each from 1985 to 2008).

forcing from ROMS which introduces annual variation in physical conditions. The distribution of numbers or biomass resulting after a simulation is informative. If the distribution has varied far from initial conditions under static fishing rates, this indicates that local conditions in the polygons cannot sustain the expected organismal distribution inputted into the model base state. On the other hand, if the end-state distributions are similar to initial conditions, then the sum effect of local habitat and predator-prey influences might portray realistic environmental conditions.

Figure 20 through Figure 24 show the late summer distributions of organisms predicted by the 2008 model after a 20-year simulation. A few representative functional groups have been selected. Figure 20 shows the distribution of reef fish. The biomass density scale is identical for all plots, so the relative density of functional groups is evident. The figures show the sum biomass through all depth layers. Single-species groups such as leopard grouper, gulf coney, and amarillo snapper show relatively less biomass overall than the highly aggregated groups such as grunts and groupers and snappers. All of the selected species concentrate in reef patches in nearshore areas.

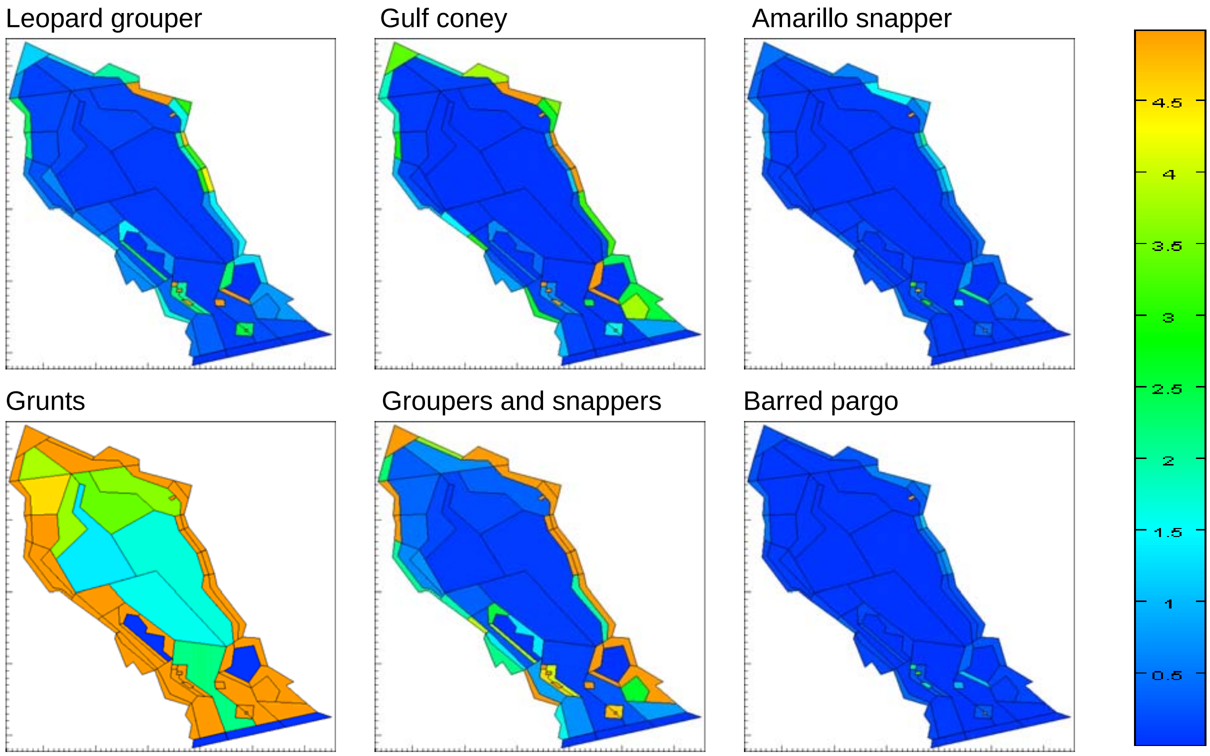


Figure 20. Predicted reef fish distribution in 2028 (mg N • m^{-2}).

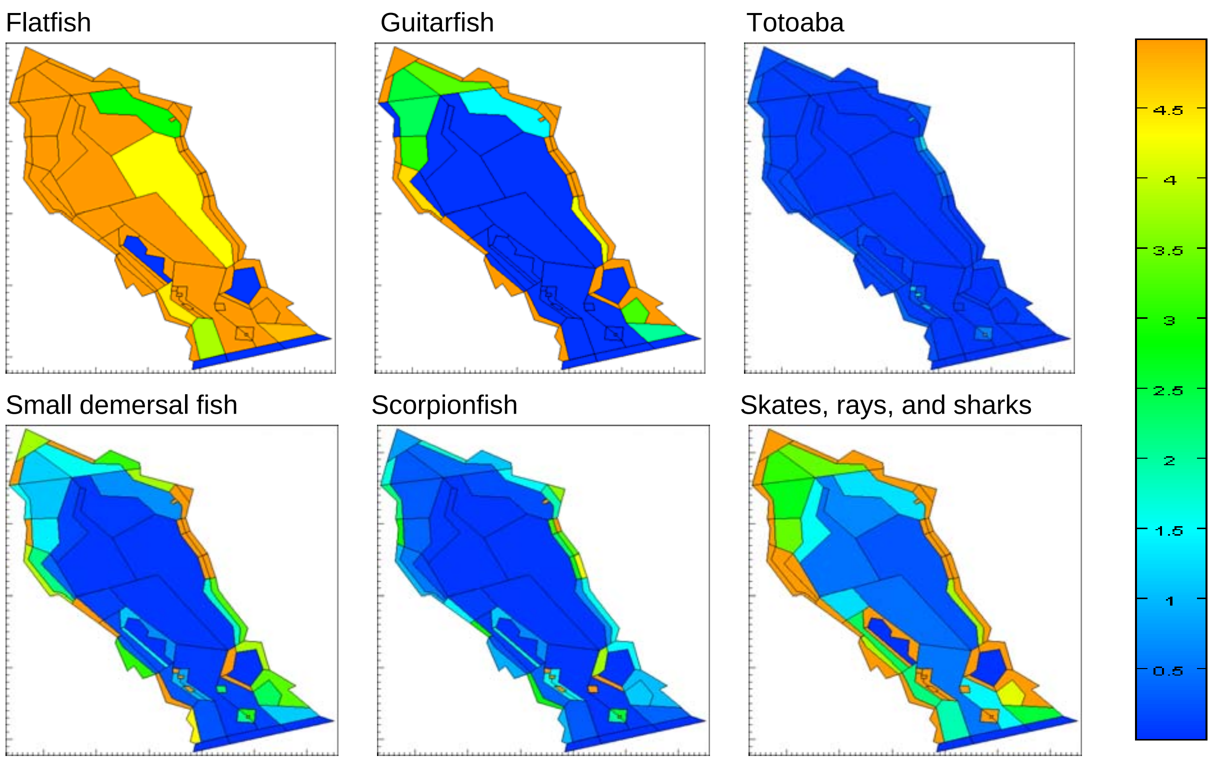


Figure 21. Predicted demersdal fish distribution in 2028 (mg N • m^{-2}).

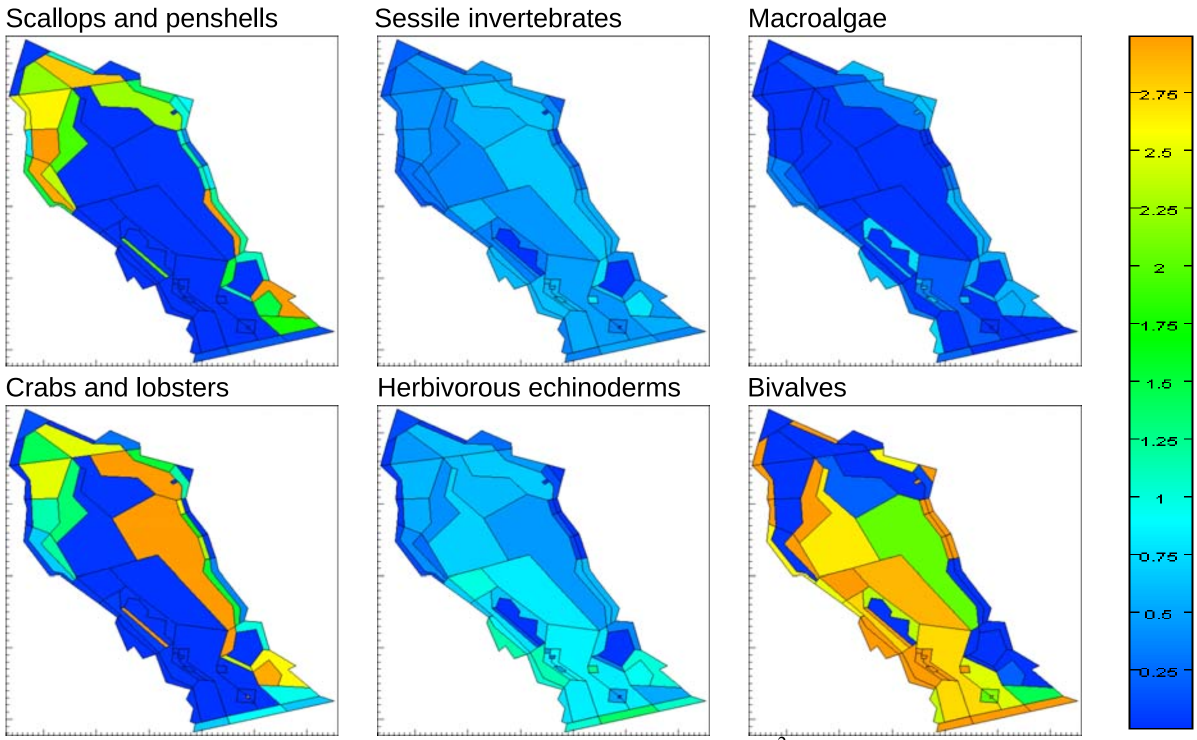


Figure 22. Predicted invertebrate distribution in 2028 (mg N • m^{-2}).

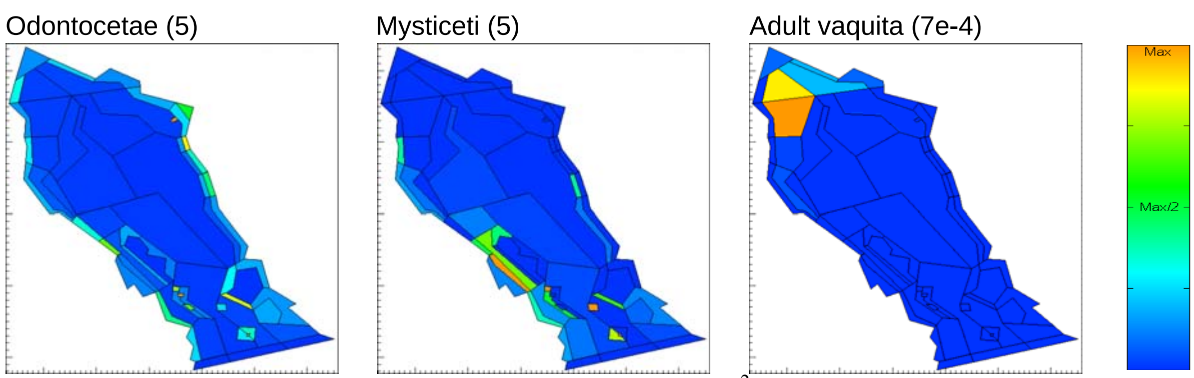


Figure 23. Predicted mammal distribution in 2028 (mg N • m^{-2}). Value in parenthesis shows color scale maximum concentration.

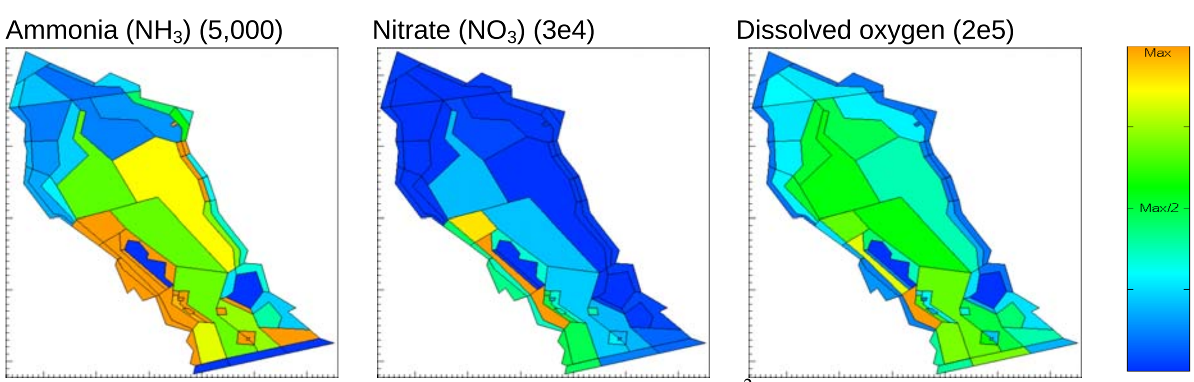


Figure 24. Predicted chemical distribution in 2028 (mg N • m^{-2}). Value in parenthesis shows color scale maximum concentration.

Figure 21 shows demersal and benthopelagic species. Again, the aggregated group flatfish has relatively high densities throughout the map at this biomass scale, while the single-species (and seriously depleted) totoaba group shows much lower densities. Skates, rays, and sharks and guitarfish tend to be more ubiquitously distributed throughout the gulf, occurring in deeper waters and soft bottom areas relative to reef fish. Both reef fish and demeral fish are distributed throughout the water column.

Figure 22 shows the distribution and biomass densities of major invertebrate groups, including exploited and nonexploited members. Figure 23 shows the distribution of mammals. Odontocetae are predicted to occur in shallow waters throughout the perimeter of the gulf, while mysticeti remain concentrated in feeding grounds in and around the Canal de Ballenas. Vaquita remain concentrated in a relatively small area in the northwest region of the gulf, which is realistic, occupying cells adjacent to San Lorenzo, occurring in the vaquita refuge and biosphere reserve.

Figure 24 shows the concentration of key chemicals in the system. Ammonia, a waste product of vertebrates and invertebrates, represents a composite indicator: it will be concentrated in areas with high densities of consumers and relatively low water mixing rates. Accordingly, we see high concentrations in the deep areas of the southwest and lower concentrations in the north of the model domain, where tidal mixing and a persistent cyclonic gyre provide constant circulation (Lavín et al. 1997). Nitrate, which is modeled in Atlantis as a limiting nutrient for primary producers, appears in low concentrations wherever primary production is high, such as the shallow and inshore areas of the northern gulf. Dissolved oxygen shows depletion in the near shore area which corresponds to regions of high productivity, perhaps reflecting wind-driven coastal upwelling (Santamaría-del-Angel et al. 1994, Gaxiola-Castro et al. 1999, Lluch-Cota et al. 2007) captured in the ROMS output.

Equilibrium Scenarios

Simulations using the present-day 2008 model demonstrate the model's suitability for future forecasts. We have developed catch and biomass equilibrium graphs in Figure D-18 through Figure D-20. This procedure is an invaluable diagnostic tool and can be used to answer fundamental questions regarding the production potential of stocks and their resilience to fishing. Surplus yield curves and biomass equilibrium curves are generated as we increase fishing mortality stepwise from zero to several times the baseline model value. At each step, the system group biomass equilibrium is established after the model runs for 30 years and residual biomass dynamics are cancelled. In Figure D-18 through Figure D-20 each point along on the x-axis corresponds to the end-state of a 30-year simulation under the specified level of fishing mortality. At the left-most extent, the biomass equilibrium curves tell us what biomass level the group assumes under zero fishing mortality (i.e., unexploited biomass or B_0).

This equilibrium is influenced by predator-prey dynamics, climate effects, and other factors. The catch equilibrium curves are analogous to single-species surplus production curves (Hilborn and Walters 1992); the maximum height of the curve shows maximum sustainable yield (MSY) of the stock and the fishing mortality at which that occurs, the F_{MSY}. In a properly parameterized model, the baseline fishing mortality of underexploited groups should be less than

F_{MSY} and greater than F_{MSY} for overexploited groups. How a functional group behaves under dynamic simulation will be greatly influenced by the relative level of exploitation represented in the model's initial conditions. The predictions can be compared to estimates derived from single-species tools and presented to fisheries experts in Mexico for the purposes of validation.

A summary of the important statistics resulting from the equilibrium analysis follows in Table 13. These values should be viewed only as indicators of model behavior; they are not accurate enough to be used in management. The behavior of several groups is obviously suspect (denoted in Table 13). Moreover, the simulations never quite reach equilibrium; part of the reason is that we have included hydrodynamic forcing from ROMS to maintain realistic physical drivers. In addition, to save time in calculating these figures, fishing mortality was applied to all groups simultaneously. To calculate fishery statistics more accurately, it would be necessary to hold the fishing mortality constant for all groups except the group being evaluated. The method we have used therefore introduces error, particularly at higher fishing mortality rates when interspecies dynamics become significant. This shortcut also ensures that the productivity of forage species is overestimated at high rates of exploitation, since their predators are being removed simultaneously. Finally, these statistics were evaluated at F = 0.0, 0.02, 0.04, 0.05, 0.06, 0.08, 0.1, 0.2, and 0.3 yr^{-1}; more gradual incremental increases are necessary to yield accurate estimates of F_{MSY}, MSY, and B_{MSY}. However, the comparison between functional groups is adequate for the purpose of model evaluation.

Table 13. Multispecies fishery statistics emerging from equilibrium analysis. Fishing mortality in 2008 (F_{2008}), fishing mortality at MSY (F_{MSY}), MSY, unexploited biomass (B_0), and biomass at MSY (B_{MSY}). Asterisk (*) denotes functional groups whose biomass dynamics may be problematic.

Group	**F_{2008}**	**F_{MSY}**	**MSY**	**B_0**	**B_{MSY}**
	(yr^{-1})			**(mt)**	
Small demersal fish	0.134	0.25	115,918	150,500	4,251,761
Small migratory sharks*	0.000	0.02	0.000	7,901	0.000005
Pacific angel shark	0.120	0.04	16	1,274	376
Guitarfish	0.004	0.02	167	685,179	524
Scorpionfish*	0.002	0.02	0.000	14,661	0.000014
Flatfish*	0.000	0.06	0.000	562,685	0.000006
Large pelagic sharks	0.095	0.06	465	74,929	8,699
Mojarra	0.105	0.30	57,772	171,466	185,746
Skates, rays, sharks	0.111	0.04	1,755	113,035	40,914
Large reef fish	0.105	0.10	8,156	122,876	82,602
Small reef fish	0.001	0.06	241	3,719,707	4,596
Gulf coney	0.166	0.15	4,676	31,690	25,644
Gulf grouper	0.103	0.10	9,828	237,121	99,714
Amarillo snapper	0.106	0.10	1,159	34,385	11,541
Herbivorous fish*	0.001	0.02	0	16,406	0.000021
Groupers and snappers*	0.000	0.08	0	468,191	0.000002
Grunts	0.007	0.20	102	168,316	10.9
Extranjero	0.130	0.10	114	3,086	1,108

Table 13 continued. Multispecies fishery statistics emerging from equilibrium analysis. Fishing mortality in 2008 (F2008), fishing mortality at MSY (F_{MSY}), MSY, unexploited biomass (B_0), and biomass at MSY (B_{MSY}). Asterisk (*) denotes functional groups whose biomass dynamics may be problematic.

Group	**F_{2008}**	**F_{MSY}**	**MSY**	**B_0**	**B_{MSY}**
	(yr^{-1})			**(mt)**	
Leopard grouper	0.005	0.02	89	13,030	646
Drums and croakers	0.000	0.02	81	763,687	2,916
Barred pargo	0.112	0.10	247	6,828	2,324
Lanternfish and deep	0.170	0.10	57,404	743,137	414,103
Large pelagics	0.094	0.15	2,665	42,326	18,628
Totoaba	0.426	0.06	9.1	24,017	12,204
Mackerel	0.094	0.15	3,054	23,138	20,983
Hake*	0.002	0.02	8.5	53,167	10.4
Small pelagics*	0.017	0.02	896	133,108	245,550
Sea birds	0.028	0.02	44	2,787	1,190
Oceanic sea turtles	0.097	0.04	7.7	393	167
Pinnipeds	0.096	0.06	249	2,592	4,570
Reef associated turtles	0.080	0.04	14	334	331
Mysticeti	0.104	0.04	418	26,278	8,925
Orca*	0.002	0.02	0.001	10,530	0.073
Odontocetae	0.097	0.04	408	27,522	11,365
Vaquita	0.099	0.02	0.308	24.1	16.9
Crabs and lobsters	0.199	0.30	92,353	165,665	165,150
Sessile invertebrates	0.100	0.04	318	24,176	8,226
Sea cucumbers	0.099	0.30	13,356	10,660	50,411
Herbivorous echinoderms	0.096	0.06	86	4,285	1,552
Carnivorous macrobenthos	0.106	0.08	3,304	113,003	39,964
Meiobenthos	0.063	0.30	5,800	12,199	45,713
Bivalves	0.127	0.30	17,799	96,128	61,320
Large zooplankton	0.000	0.02	0.000	42,884	79,850
Penaeid shrimp	13.768	0.15	1,487	37,450	32,351
Macroalgae	0.096	0.04	78	5,675	2,094
Microphytobenthos	0.395	0.10	20	193	513
Seagrass	0.098	0.05	219	20,146	4,559
Scallops and penshells	4.644	0.08	12	9,356	7,154
Jellyfish*	0.132	0.30	9,110,328	32,110,529	19,487,338

Discussion

Beyond Single-species Methods

When single species fisheries assessment methods were developed in the mid-twentieth century, there were relatively few species exploited in most marine ecosystems, low levels of fishing pressure, and few marine industries that competed with fisheries (Sissenwine 1978). The complexity at which population dynamics could be modeled was also very limited (Mangel and Levin 2005) and this contributed to a reliance on simple analytical solutions. Considering stocks in isolation was therefore appropriate. Today, human-induced pressures on the natural system have intensified and diversified in exploited marine ecosystems, such as the northern Gulf of California. There are now other important marine industries in addition to commercial fisheries, for example, recreational fisheries, aquaculture, ecotourism, and oil and gas exploration and production.

As more marine sectors vie for control of space and resources, we need improved quantitative tools to weigh competing socioeconomic costs and benefits as an aid to policy makers. There is also increasing recognition that climate impacts must be factored into policy decisions (Crowder et al. 2008). Fisheries management has therefore become a more complex affair. However, the last 20 years have also seen amazing advances in ecological modeling and progress made in ecosystem science has been dramatic. Inexpensive computing power and the timely interest of funding agencies has made possible new tools such as Atlantis, which will allow marine managers to consider complex and synergistic effects of management policies in a new and powerful way. Continued development and use of these models is an important step towards satisfying the technical requirements of EBFM.

In support of that goal, this project has broken new ground in several ways. Targeted acquisition of field data to support development of an ecosystem model is rare, and we have had several such opportunities in the Gulf of California modeling project, including the trawl and diving transect program to provide biomass data, morphometric measurements to set gape-restriction, stomach sampling to provide a diet matrix, port-level surveys to estimate unreported catch, and community interviews to reconstruct a relative abundance time series for model tuning. Meanwhile, new methodological advances have helped progress the field: development of the biomass allocation algorithm, statistical analysis of diet composition, and rationalization of anecdotal interview data through fuzzy logic—all of which serve to consolidate information into a form usable by Atlantis. The project continues to innovate. At the time of writing, Atlantis has been reprogrammed to incorporate larval dispersion, while calculations made using the ROMS model described herein will form the connectivity matrix to define larval exchange and source-sink dynamics between Atlantis polygons.

Status of the Models

The simulations detailed in this report serve as a demonstration of the operational status of the models. Although there is much more that can be done to improve behavior, the models have shown stable over a wide range of conditions. The 1985 model has been run under a no-fishing scenario and an historical reconstruction scenario. The no-fishing scenario resulted in elevated biomass levels with stable equilibria for most functional groups that agreed with previous estimates of unexploited biomass (Figure 19). The historical reconstruction scenario successfully reconstructed known trends of relative abundance for the majority of groups (Figure D-16 and Figure D-17); forecasts made from 1985 to 2008 conformed either to known stock assessement trends or to the relative abundance estimated using LEK information in Ainsworth (in press) with only five to six groups showing serious discrepencies.

The 2008 model has been evaluated over a wide range of fishing mortalities, from zero to 0.3 yr^{-1}, and showed believable responses in 40 out of 49 functional groups (Table 13), while individual weight diagnostics seem well behaved, indicating that the availabilities matrix and consumption rate parameters are commensurate with predator and prey abundances and production rates. The process of transferring the dynamic parameters from the 1985 to 2008 model, thus assuming stationarity in key foraging behaviors, prey preferences, and population statistics (see 1985 historical model subsection), proved to be a valid method, as the 2008 model required very little manipulation afterwards and assumed reasonable dynamics that were similar to the (tuned) 1985 model behavior.

The process of constructing Atlantis models is a heuristic exercise, since all parameters must be compatable from trophodynamic and thermodynamic perspectives. One of the most important findings of this study is that catch estimates from official Mexican sources proved to be far too low to have resulted in the species declines suggested by both stock assessment and LEK information. The catch multipliers in Table 10, which account for discards as well as unreported catch, show the approximate degree of the discrepancy. In broad terms, reef fish, which are targets of large and unregulated artisanal fisheries, are underestimated in the statistics by a factor of 4–5 times, while invertebrates are underestimated 1–3 times (note that the base values include port-level surveys of catch, and so largely reflect discards and incidental mortality). The values for aggregate groups, which generally include a high fraction of untargeted species, are higher still (>15 times for reef fish species). This mainly reflects the fact that very few of these low-value species are accounted for in statistics. The records for pelagic fish, which are usually lumped together in fishery statistics with catch estimates from the Pacific, must be decreased by 60% to 90% to account for catches originating only in the northern gulf.

Generally, population dynamics are predicted well in species for which fishing is a dominant source of mortality. For species that suffer a higher proportional degree of predation mortality (e.g., lanternfish), are heavily affected by climate variation (e.g., small reef fish, small pelagics), or whose population trends are determined by factors operating outside of the model domain (e.g., orca, mysticeti), population trends are poorly predicted by the model when driven only by local fishery and oceanographic influences. Similar behavior is noted in previous Atlantis applications (Fulton et al. 2011), although these problems are common to a wide variety of fisheries and ecological modeling approaches.

One of the intended uses of the Atlantis models is to test species recovery plans. In the case of vaquita, it is difficult to gauge the actual level of fishing or incidental kills that occur since fishers may well avoid sharing such information. Without a reliable estimate, we assumed zero kills per year. Under those conditions, Atlantis suggests that the population should recover relatively quickly (Figure D-4). However, assuming a fishing mortality rate of 17% per year (Barlow et al. 1997) results in extinction (Figure D-18). Within 15 years, the number of individuals is predicted to be fewer than 10, although that time horizon is certainly overestimated since Atlantis does not account for depensatory mortality caused by inbreeding depression or stochasticity. Totoaba show a similar response in the model: their population is predicted to increase quickly upon fishing release. Unreported catch remains a plausible factor responsible for the depressed populations of these species.

Future Applications

Forthcoming publications will use this model to test efficacy of current regulations under a full-enforcement scenario; test various marine spatial management scenarios including implementation of no-take and restricted-take marine protected areas; test species-level regulations involving effort restrictions, seasonal closures, mesh and hook size changes; and test efficacy of catch shares programs. These EBFM scenario guidelines for testing in the model are currently being developed through cooperation between NWFSC, PANGAS partners, CONAPESCA, and INAPESCA. Ecological hypotheses can also be effectively investigated using the Atlantis framework. Further studies could answer questions related to wetland preservation, climate change and climate variability, nutrification, species recovery, and the effect of episodic pulses of freshwater from the Colorado River related to El Niño events.

The northern Gulf of California Atlantis model should serve as a useful tool in years to come and support an ongoing effort to implement EBFM in Mexico. The model stands ready for new applications testing EBFM strategies and ecological scenarios. The authors therefore invite interested students and researchers in Mexico or elsewhere to continue to build on the work described here. To help facilitate this, Atlantis training programs have been conducted in Mexico and the United States and the effort is ongoing. Meanwhile, the Atlantis user community continues to grow through the efforts of CSIRO and NWFSC. New online support tools such as the Atlantis webpage (http://Atlantis.cmar.csiro.au/) and wiki (https://wiki.csiro.au /confluence/) help users construct models, stay up-to-date on software changes, and troubleshoot problems.

Atlantis is now recognized as one of the most promising approaches for marine ecosystem studies (Plagányi 2007). It can play an important role in NWFSC's integrated ecosystem assessment process (Levin et al. 2009) as a means to carry out management strategy evaluation, a process in which management policies are evaluated with due regard for scientific and implementation uncertainty (Sainsbury et al. 2000, Fulton et al. 2007b). Recently, CSIRO launched a concerted effort to improve functionality and usability of Atlantis, an effort supported by the Gordon and Betty Moore Foundation, CSIRO, and other funders. We can therefore expect the usefulness and long-term prospects of this modeling approach to continue to improve and lend aid to marine ecosystem management in Mexico and the world.

References

Abdel-Aziz, S. H., A. H. Khalil, and S. A. Abdel-Maguid. 1993. Reproductive cycle of the common guitarfish, *Rhinobatos rhinobatos* (Linnaeus 1758), in Alexandria Waters, Mediterranean Sea. Aust. J. Mar. Fresh. Res. 44:507–517.

Aburto-Oropeza, O., B. Erisman, C. Valdez-Ornelas, and G. Danemann. 2008a. Commercially important serranid fishes from the Gulf of California: Ecology, fisheries, and conservation. Ciencia y Conservación 2008(1):1–44.

Aburto-Oropeza, O., B. Erisman, C. Valdez-Ornelas, and G. Danemann. 2009. Serránidos de importancia comercial del Golfo de California: Ecología, pesquerías y conservación. Ciencia y Conservación 2009(1):1–44.

Aburto-Oropeza, O., E. Ezcurra, G. Danemann, V. Valdez, J. Murray, and E. Sala. 2008b. Mangroves in the Gulf of California increase fishery yields. Proc. Natl. Acad. Sci. USA 105:10456–10459.

Adey, W. H., and K. Loveland. 1991. Dynamic aquaria. Academic Press, San Diego, CA.

Aguilar-Rosas, L. E., R. Aguilar-Rosas, A. C. Mendoza-González, and L. E. Mateo-Cid. 2000. Marine algae from the northeast coast of Baja California, Mexico. Bot. Mar. 43:127–139.

Ainsworth, C. H. In press. Quantifying species abundance trends in the northern Gulf of California using local ecological knowledge. Mar. Coast. Fish.

Ainsworth, C. H., I. C. Kaplan, P. S. Levin, and M. Mangel. 2010. A statistical approach for estimating fish diet compositions from multiple data sources: Gulf of California case study. Ecol. Appl. 20:2188–2202. Online at http://www.esajournals.org/doi/pdf/10.1890/09-0611.1 [accessed 27 September 2010].

Ainsworth, C. H., T. J. Pitcher, and C. Rotinsulu. 2008a. Evidence of fishery depletions and shifting cognitive baselines in eastern Indonesia. Biol. Conserv. 141:848–859.

Ainsworth, C. H., D. Varkey, and T. J. Pitcher. 2007. Ecosystem simulation models for the Bird's Head Seascape, Papua, fitted to data. *In* T. J. Pitcher, C. H. Ainsworth, and M. Bailey (eds.), Ecological and economic analyses of marine ecosystems in the Birds Head seascape, Papua, Indonesia, p. 6–172. Fisheries Centre Research Reports, University of British Columbia, Vancouver.

Ainsworth, C. H., D. Varkey, and T. J. Pitcher. 2008b. Ecosystem simulations supporting ecosystem-based fisheries management in the Coral Triangle, Indonesia. Ecol. Model. 214:361–374.

Alfredo Arreola, J. Unpubl. data. Species and taxa sampling. (Available from J. Alfredo Arreola, Centro de Investigaciones Biologicas del Noroeste, Mar Bermejo No. 195, Col. Playa Palo de Santa Rita Apdo. Postal 128; La Paz, BCS 23090, Mexico.)

Allen, G. R. 1985. FAO species catalogue. Vol. 6. Snappers of the world: An annotated and illustrated catalogue of lutjanid species known to date. U.N. Food and Agriculture Organization Fisheries Synopsis 125:208, FAO, Rome.

Almeida-Paz, M., G. Morales-Abril, and M. J. Román-Rodriguez. 1992. Aspectos sobre aclimatación y crecimiento de juveniles de totoaba, *Totoaba macdonaldi* (Gilbert) (Pisces: Sciaenidae) en condiciones de cautiverio. Ecológica 2:7–12.

Alvarez-Borrego, S. 2003. Physical and biological linkages between the upper and lower Colorado delta. *In* D. J. Rapport, W. L. Lasley, D. E. Rolston, N. O. Nielsen, C. O. Qualset, and A. B. Damania (eds.), Managing for health ecosystems, p. 1077–1089. CRC Press, Boca Raton, FL.

Alvarez-Borrego, S., and L. A. Galindo-Bect. 1974. Hidrologia del Alto Golfo de California-I. Condiciones durante otonó. Cienc. Mar. 1:46–64.

Alvarez-Borrego, S., and G. Gaxiola-Castro. 1988. Photosynthetic parameters of northern Gulf of California phytoplankton. Cont. Shelf Res. 8:37–47.

Alvarez-Sánchez, L. G., V. M. Godínez, M. F. Lavín, and S. Sánchez. 1993. Patrones de turbidez y corrientes en la Bahı´a de San Felipe, al NW del Golfo de California. Communicaciones Académicas CICESE CTOFT-9304:48.

Ambrose, R. F. 1984. Food preferences, prey availability, and the diet of *Octopus bimaculatus* Verrill. J. Exp. Mar. Biol. Ecol. 77:29–44.

Anadón, J. D., A. Giménez, R. Ballestar, and I. Pérez. 2009. Evaluation of local ecological knowledge as a method for collecting extensive data on animal abundance. Conserv. Biol. 23:617–625.

Angliss, R. P., and K. L. Lodge. 2002. Alaska marine mammal stock assessments, 2002. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-133.

Aragón-Noriega, E. A., and L. E. Calderón-Aguilera. 2000. Does damming of the Colorado River affect the nursery area of blue shrimp *Litopenaeus stylirostris* (Decapoda: Penaeidae) in the upper Gulf of California? Rev. Biol. Trop. 48:867–871.

Argote, M. L., A. Amador, M. F. Lavín, and J. R. Hunter. 1995. Tidal dissipation and stratification in the Gulf of California. J. Geophys. Res. 100:16103–16118.

Aridjis, H. 1990. Mexico proclaims total ban on harvest of turtles and eggs. Marine Turtle Newsletter 50:1–3. Online at http://www.seaturtle.org/mtn/archives/mtn50/mtn50p1.shtml [accessed 27 September 2010].

Arreguin-Sánchez, F., E. Arcos, and E. A. Chavez. 2002. Flows of biomass and structure in an exploited benthic ecosystem in the Gulf of California, Mexico. Ecol. Model. 156:167–183.

Arreguín-Sánchez, F., L. Beléndez-Moreno, I. M. Gómez-Humarán, R. Solana-Sansores, and C. Rangel-Dávalos. 2006. Sustentabilidad y Pesca Responsable en Mexico. Instituto Nacional de la Pesca. Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion.

Arreguín-Sánchez, F., A. Hernández-Herrera, M. Ramírez-Rodríguez, and H. Pérez-Espana. 2004. Optimal management scenarios for the artisanal fisheries in the ecosystem of La Paz Bay, Baja California Sur, Mexico. Ecol. Model. 172:373–382.

Arthur, K. E., M. C. Boyle, and C. J. Limpus. 2008. Ontogenetic changes in diet and habitat use in green sea turtle (*Chelonia mydas*) life history. Mar. Ecol. Prog. Ser. 362:303–311.

Arvizu, J., and H. Chavez. 1970. Synopsis of the biology of the totoaba *Cynoscion Macdonaldi* Gilbert 1890. U.N. Food and Agriculture Organization (FAO) Fisheries Synopsis 108:21. FAO, Rome.

Bakun, A., E. Babcock, D. B. Lluch-Cota, C. Santora, and C. J. Salvadeo. 2009. Issues of ecosystem-based management of forage fisheries in open non-stationary ecosystems: The example of the sardine fishery in the Gulf of California. Rev. Fish Biol. Fish. 20(1):9–29.

Barlow, J., and P. Boveng. 1991. Modeling age mortality for marine mammal populations. Mar. Mammal Sci. 7(1):50–65.

Barlow, J., T. Gerrodette, and G. Silber. 1997. First estimates of vaquita abundance. Mar. Mammal Sci. 13:44–58.

Barnard, A. H., J. R. V. Zaneveld, W. S. Pegau, J. L. Mueller, H. Maske, R. L. Lara, A. A. Borrego, R. C. Duarte, and E. V. Holguín. 1999. The determination of PAR levels from absorption coefficient profiles at 490 nm. Cienc. Mar. 25:487–507.

Baumgartner, T. R., and N. Christensen. 1985. Coupling of the Gulf of California to large-scale interannual climatic variability. J. Mar. Res. 43:825–848.

Bazán-Guzmán, M. C. 1990. Productividad primaria en la parte sur y central del Golfo de California durante Noviembre-Diciembre de 1984. Bachelor's thesis. Universidad Nacional Autonoma de Baja California, Ensenada, BC, Mexico.

Beier, E. 1997. A numerical investigation of the annual variability in the Gulf of California. J. Phys. Oceanogr. 27:615–632.

Berdegue, J. 1955. La pesqueria de la totoaba (*Cynoscion Macdonaldi* Gilbert) en San Felipe, Baja California. Revista de la Sociedad Mexicana de Historia Natural 16:45–76.

Bizzarro, J. 2005. Fishery biology and feeding ecology of rays in Bahia Almejas, Mexico. San Francisco State Univ., San Francisco, CA.

Booth, A. J., and E. D. Isted. 1997. Comparison of methods used to convert length-frequency data. Fish. Res. 29:271–276.

Boyle, M. C., and C. J. Limpus. 2008. The stomach contents of post-hatchling green and loggerhead sea turtles in the southwest Pacific: An insight into habitat association. Mar. Biol. 155:233–241.

Brand, E. J., I. C. Kaplan, C. J. Harvey, P. S. Levin, E. A. Fulton, A. J. Hermann, and J. C. Field. 2007. A spatially explicit ecosystem model of the California Current's food web and oceanography. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-84.

Brook, R. K., and S. M. McLachlan. 2005. On using expert-based science to "test" local ecological knowledge. Ecol. Soc. 10(2):r3.

Bruland, K. W., E. L. Rue, and G. J. Smith. 2001. Iron and macronutrients in California coastal upwelling regimes: Implications for diatom blooms. Limnol. Oceanogr. 46:1661–1674.

Brusca, R. C. 2006. Invertebrate biodiversity in the northern Gulf of California. *In* R. S. Felger and W. Broyles (eds.), Dry borders, p. 418–504. Great natural reserves of the Sonoran Desert. University of Utah Press, Salt Lake City.

Brusca, R. C., J. Campoy-Fabela, C. Castillo-Sánchez, R. Cudney-Bueno, L. T. Findley, J. Garcia-Hernández, E. Glenn, I. Granillo, M. E. Hendrickx, J. Murrieta, C. Nagel, M. Román, and P. Turk-Boyer. 2001. A case study of two Mexican biosphere reserves. The upper Gulf of California/Colorado River delta and Pinacate/Gran Desierto de Altar Biosphere Reserves. Unidad CIAD Guaymas, Sonora, Mexico.

Brusca, R. C., L. T. Findley, P. Hastings, M. E. Hendrickx, J. Torre Cosio, and A. M. van der Heiden. 2005. Macrofaunal biodiversity in the Gulf of California. *In* J.-L. E. Cartron, G. Ceballos, and R. Felger (eds.), Biodiversity, ecosystems, and conservation in northern Mexico. Oxford University Press, New York.

Bustos-Serrano, H., and R. Castro-Valdez. 2005. Flux of nutrients in the Gulf of California: Geostrophic approach. Mar. Chem. 99:210–219.

Caceres-Martinez, C., J. Chavez-Villalba, and L. Garduno-Mendez. 2005. First record of *Pseudomyicola spinosus* in *Argopecten ventricosus* in Baja California, Mexico. J. Invertebr. Pathol. 89:95–100.

Carbajal, N., A. Souza, and R. Durazo. 1997. A numerical study of the ex-ROFI [region of freshwater influence] of the Colorado River. J. Mar. Syst. 12:17–33.

Cárdenas-Torres, N., R. Enríquez-Andrade, and N. Rodríguez-Dowdell. 2007. Community-based management through ecotourism in Bahia de los Angeles, Mexico. Fish. Res. 84:114–118.

Cárdenas, E. B., and D. A. Aranda. 2000. A review of reproductive patterns of bivalve mollusks from Mexico. Bull. Mar. Sci. 66:13–27.

Carriquiry, J. D., and A. Sanchez. 1999. Sedimentation in the Colorado River delta and upper Gulf of California after nearly a century of discharge loss. Mar. Geol. 158:125–145.

Casas-Valdez, M., and G. Ponce-Díaz (eds.). 1996. Estudio del potencial pesquero y acuícola de Baja California Sur. Vol 1. SEMARNAP-Gobierno del Estado de B.C.S.-FAO-INP-UABCS-CIB-CICIMAR-CETMAR. Mexico.

Case, T. J., M. L. Cody, and E. Ezcurra. 2002. A new island biogeography of the Sea of Cortes. Oxford University Press, New York.

Castaneda-Fernandez-de-Lara, V., E. Serviere-Zaragoza, and S. Hernandez-Vazquez. 2005. Feeding ecology of juvenile spiny lobster, *Panulirus interruptus*, on the Pacific coast of Baja California Sur, Mexico. New Zeal. J. Mar. Fresh. Res. 39:425–435.

CEDO Intercultural (Centro Intercultural de Estudios de Desiertos y Oceanos). Unpubl. data. Species summary ficha. (Available from info@cedointercultural.org.)

Chalcraft, D. R., and W. H. Resetarits. 2003. Predator identity and ecological impacts: Functional redundancy or functional diversity? Ecology 84:2407–2418.

Chaloupka, M. Y., and C. J. Limpus. 2002. Survival probability estimates for the endangered loggerhead sea turtle resident in southern Great Barrier Reef waters. Mar. Biol. 140:267–277.

Cheung, W. W. L., T. J. Pitcher, and D. Pauly. 2005. A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing. Biol. Conserv. 124:97–111.

Christensen, V., and D. Pauly. 1992. ECOPATH II–A software for balancing steady-state models and calculating network characteristics. Ecol. Model. 61:169–185.

Christensen, V., and C. Walters. 2005. Using ecosystem modeling for fisheries management: Where are we? International Council for the Exploration of the Sea (ICES) CM 2005/M:19. Online at http://www.ices.dk/products/CMdocs/2005/M/M1905.pdf [accessed 27 September 2010].

Chute, G. R. 1928. The totuáva fishery of the California Gulf. Calif. Fish Game 14:275–281.

Cisneros-Mata, M. A., L. W. Botsford, and J. F. Quinn. 1997. Projecting viability of *Totoaba macdonaldi*, a population with unknown age-dependent variability. Ecol. Appl. 7:968–980.

Cisneros-Mata, M. A., G. Montemayor-López, and M. J. Román-Rodríguez. 1995. Life history and conservation of *Totaba macdonaldi*. Conserv. Biol. 9:806–814.

COBI (Comunidad y Biodiversidad). Unpubl. data. Species summary ficha. (Available from cobi@cobi.org.mx.)

CONAPESCA (Comisión Nacional de Aquacultura y Pesca). 2009. Anuario estadistico de acuacultura y pesca (1980–2000). CONAPESCA, Mazatlan, Sinaloa, Mexico.

Cortés, E. 1999. Standardized diet compositions and trophic levels of sharks. ICES J. Mar. Sci. 56:707–717.

Crowder, L. B., E. L. Hazen, N. Avissar, R. Bjokland, C. Latanich, and M. B. Ogburn. 2008. The impacts of fisheries on marine ecosystems and the transition to ecosystem-based management. Annu. Rev. Ecol. Evol. Syst. 39:259–278.

Cruz-Romero, M., E. A. Chavez, E. Espino, and A. Garcia. 1996. Assessment of a snapper complex (*Lutjanus* spp.) of the eastern tropical Pacific. *In* J. L. M. F. Arregin-Sanchez, M. C. Balgos, and D. Pauly (eds.), Biology, fisheries, and culture of tropical groupers and snappers, p. 324–330. International Center for Living Aquatic Resources Management (ICLARM) Conf. Proc.

Cudney-Bueno, R. Unpubl. data. Bullseye pufferfish. (Available from R. Cudney-Bueno, David and Lucile Packard Foundation, 300 Second St., Los Altos, CA 94022.)

Cudney-Bueno, R., M. Lavin, P. Raimondi, J. Torre, and P. Turk-Boyer. 2007. PANGAS field sampling database (updated 7 April 2007). Univ. Arizona, Tucson. (Available from R. Cudney-Bueno, David and Lucile Packard Foundation, 300 Second St., Los Altos, CA 94022.)

Cudney-Bueno, R., and P. Turk-Boyer. 1998. Pescando entre mareas del alto Golfo de California: Una guía sobre la pesca artesanal, su gente y sus propuestas de Manejo. Centro Intercultural de Estudios de Desiertos y Océanos, Puerto Peñasco, Sonora, Mexico.

Cury, P. M., Y. Shin, B. Planque, J. Curant, J. Fromentin, S. Kramer-Schadt, N. Stenseth, M. Travers, and V. Grimm. 2008. Ecosystem oceanography for global change in fisheries. Trends Ecol. Evol. 23:338–346.

Cushing, D. H., G. F. Humpfrey, K. Banse, and T. Laevastu. 1958. Report of the Committee on Terms and Equivalents. Rapports et proces-verbaux des reunions du conseil international pour l´exploration de la mer 144:15–16.

Cuzon, G., L. Arena, J. Goguenheim, and E. Goyard. 2004. Is it possible to raise offspring of the 25th generation of *Litopenaeus vannamei* (Boone) and 18th generation *Litopenaeus stylirostris* (Stimpson) in clear water to 40 g? Aquacult. Res. 35:1244–1252.

D'Agrosa, C., C. E. Lennert-Cody, and O. Vidal. 2000. Vaquita bycatch in Mexico's artisanal gill net fisheries: Driving a small population to extinction. Conserv. Biol. 14:1110–1119.

D'Agrosa, C., O. Vidal, and W. C. Graham. 1995. Mortality of the vaquita (*Phocoena sinus*) in gill net fisheries during 1993–94. Report of the International Whaling Commission Special Issue 16.

Danemann, G. D., and E. Ezcurra (eds.). 2007. Bahia de los Angeles: Recursos naturales y comunidad. Línea base 2007. Pronatura Noroeste AC, Secretaría de Medio Ambiente y Recursos Naturales. Instituto Nacional de Ecología. San Diego Natural History Museum, Ensenada, BC, Mexico.

DaSilva, A. M., C. C. Young, and S. Levitus. 1994. Atlas of surface marine data 1994, vol. 1: Algorithms and procedures. NOAA Atlas NESDIS 6. U.S. Dept. Commer., NOAA, National Environmental Satellite, Data, and Information Service, Silver Spring, MD.

DeCraene, L., and W. Fink. 2004. Squatina california. Animal diversity web. Univ. Michigan, Ann Arbor.

Desortová, B. 1981. Relationship between chlorophyll *a* concentration and phytoplankton biomass in several reservoirs in Czechoslovakia. Internationale Revue der gesamten Hydrobiologi und Hydrographie 66:153–169.

Diario Oficial de la Federación. 1990. Acuerdo por el que se establece veda para las especies y subespecies de tortuga marina en aguas de jurisdicción federal del Golfo de Mexico y Mar Caribe, así como en las costas del Océano Pacifico, incluyendo el Golfo de California. Mexico City. Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT).

Diario-Oficial de la Federación. 1993. Decreto por el que se declara area natural protegida con el caracter de Reserva de la Biosfera, la region conocida como alto Golfo de California y delta del Rio Colorado, ubicada en aguas del Golfo de California y los municipios de Mexicali, BC, del Puerto Penasco y San Luis Rio Colorado, Sonora. *In* Diario oficial de la federación, Jueves 10 de Junio de 1993, Mexico City.

Diario Oficial de la Federación. 2001. Protección ambiental-especies nativas de Mexico de flora y fauna silvestres, categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-lista de especies en riesgo. *In* Diario Oficial de la Federación, Miércoles 6 de Marzo de 2002, p. 1–153. Secretaria de Medio Ambiente y Recursos Naturales, NOM-059-SEMARNAT-2001.

Diario Oficial de la Federación. 2002. Decreto por el que se declara área natural protegida con la categoría de reserva de la biosfera, la región denominada Isla San Pedro Mártir, ubicada en el Golfo de California, frente a las costas del Municipio de Hermosillo, Estado de Sonora, con una superficie total de 30,165-23-76.165 hectáreas. *In* Diario Oficial de la Federación, Lunes 25 de Abril de 2005, p. 1–14. Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT).

Diario Oficial de la Federación. 2004a. Convenio de coordinacion que celbran la Secretaria de Seguridad Publica y el Estado de Nayarit, para la realizacion de acciones en materia de seguridad publica en el ano 2004. *In* Diario Oficial de la Federación, Lunes 15 de Marzo de 2004, p. 1–180. Secretaria de Seguridad Publica.

Diario Oficial de la Federación. 2004b. Segunda seccion. Secretaria de agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion. *In* Diario Oficial de la Federación, Lunes 15 de Marzo de 2004, Mexico City.

Diario Oficial de la Federación. 2005. Decreto por el que se declara área natural protegida, con la categoría de parque nacional, exclusivamente la zona marina que circunda al complejo insular conocido como Archipiélago de San Lorenzo, ubicada en el Golfo de California, frente a las costas del Municipio de Ensenada, Estado de Baja California, con una superficie total de 58,442-80-45.40 hectáreas. *In* Diario Oficial de la Federación, Lunes 25 de Abril de 2005, p. 1–15. Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT).

Diario Oficial de la Federación. 2006a. Carta Nacional Pesquera, Segunda Sección. Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion (SAGARPA), Mexico City.

Diario Oficial de la Federación. 2006b. Primera Seccion. Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion (SAGARPS). *In* Diario Oficial de la Federación, Viernes 25 de Agosto de 2006, Mexico City.

Diario Oficial de la Federación. 2007. Decreto por el que se declara área natural protegida, con la categoría de reserva de la biosfera, la zona marina conocida como Bahía de los Angeles, canales de Ballenas y de Salsipuedes, comprendiendo la zona federal marítimo terrestre correspondiente a la porción de la costa oriental de la península de Baja California, ubicada frente al Municipio de Ensenada, en el Estado de Baja California. *In* Diario Oficial de la Federación, Martes 5 de Junio de 2007, p. 1–19. Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT).

Diaz-Uribe, J. G., F. Arreguín-Sánchez, and M. A. Cisneros-Mata. 2007. Multispecies perspective for small-scale fisheries management: A trophic analysis of La Paz Bay in the Gulf of California, Mexico. Ecol. Model. 201:205–222.

Dizon, A. E., C. A. Lux, R. G. Leduc, J. Urbán-Ramírez, M. Henshaew, and R. L. Brownell. 1995. An interim phylogenetic analysis of sei and Bryde's whale mitochondrial DNA control region sequences. *In* Trabajo SC/47/NP23 presentado al Comité Científico de la International Whaling Commission.

Egbert, G. D., and S. Y. Erofeeva. 2002. Efficient inverse modeling of barotropic ocean tides. J. Atmos. Ocean. Tech. 19(2):183–204.

Enriquez-Andrade, R., G. Anaya-Reyna, J. C. Barrera-Guevara, M. D. Carvajal-Moreno, M. E. Martinez-Delgado, J. Vaca-Rodriguez, and C. Valdes-Casillas. 2005. An analysis of critical areas for biodiversity conservation in the Gulf of California Region. Ocean Coast. Manage. 48:31–50.

European Commission. 2008. Communication from the commission to the council and the European Parliament. The role of the CFP in implementing an ecosystem approach to marine management. SEC(2008). Commission of the European Communities, Brussels.

FAO (United Nations Food and Agriculture Organization). 2003. The ecosystem approach to fisheries. FAO Tech. Guidel. Responsible Fish. 4:112. FAO, Rome.

Färber-Lorda, J., A. Trasviña, and P. C. Verdín. 2004. Trophic condtions and zooplankton distribution in the entrance of the Sea of Cortés during summer. Deep-Sea Res. Pt. II Top. Stud. Oceanogr. 51:615–627.

Farfán, C., and S. Alvarez-Borrego. 1992. Zooplankton biomass of the northernmost Gulf of California. Cienc. Mar. 18:17–36.

Felger, R. 2000. Flora of the Gran Desierto and Río Colorado of northwestern Mexico. University of Arizona Press, Tucson.

Felger, R., W. J. Nichols, and J. A. Seminoff. 2005. Sea turtles in northwestern Mexico: Conservation, ethnobiology, and desperation. *In* J. L. Cartron, G. Ceballos, and R. Felger (eds.), Biodiversity, ecosystems, and conservation in northern Mexico, p. 405–424. Oxford University Press, New York.

Findley, L. T., and R. C. Brusca. 2005. Presentation of the data. Arizona-Sonora Desert Museum and Conservation International, Tucson, AZ.

Flanagan, C. A., and J. R. Hendrickson. 1976. Observations on the commercial fishery and reproductive biology of the totoaba, *Cynoscion macdonaldi*, in the northern Gulf of California. Fish. Bull. 74:531–544.

Flessa, K. W. 2004. Ecosystem services and the value of water in the Colorado River delta and estuary, USA and Mexico: Guidelines for mitigation and restoration. *In* International Seminar on Restoration of Damaged Lagoon Environments, p. 79-86. Matsue, Japan.

Flessa, K. W., D. L. Dettman, B. R. Shöne, D. H. Goodwin, C. A. Rodriquez, S. K. Noggle, M. A. Téllez-Duarte, G. E. Avila-Serrano, M. Kowalewski, and G. A. Goodfriend. 2001. Since the dams: Historical ecology of the Colorado delta (poster presentation) in United States-Mexico. Colorado River Delta Symposium, Mexicali, BC, Mexico.

Ford, J. K. B., G. A. Ellis, L. G. Barrett-Lennard, A. B. Morton, R. S. Palm, and K. C. Balcomb. 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British Columbia and adjacent waters. Can. J. Zool. 76:1456–1471.

Ford, J. K. B., G. A. Ellis, D. R. Matkin, K. C. Balcomb, D. Briggs, and A. B. Morton. 2005. Killer whale attacks on minke whales: Prey capture and antipredator tactics. Mar. Mammal Sci. 21:603–618.

Fouts, W. R., and D. R. Nelson. 1999. Prey capture by the Pacific angel shark, *Squatina californica*: Visually mediated strikes and ambush-site characteristics. Copeia 1999:304–312.

Franco-Gordo, C., E. Godínez-Domínguez, A. E. Filonov, I. E. Tereshchenko, and J. Freire. 2004. Plankton biomass and larval fish abundance prior to and during the El Nino period of 1997–1998 along the central Pacific coast of Mexico. Prog. Oceanogr. 63:99–123.

Froese, R., and D. Pauly. 2007. FishBase. World wide web electronic publication. Online at http://www.fishbase.org/search.php [accessed 24 September 2010].

Fulton, E. A. 2001. The effects of model structure and complexity on the behavior and performance of marine ecosystem models. University of Tasmania, Hobart, Australia.

Fulton, E. A., J. Link, I. C. Kaplan, M. Savina-Rolland, P. Johnson, C. H. Ainsworth, P. J. Horne, R. Gorton, R. Gamble, A. D. M. Smith, and D. C. Smith. 2011. Lessons in modeling and management of marine ecosystems: The Atlantis experience. Fish Fish. Online at http://dx.doi.org [DOI name 10.1111/j.1467–2979.2011.00412.x, accessed 21 February 2011].

Fulton, E. A., T. Morato, and T. J. Pitcher. 2007a. Modeling seamount ecosystems and their fisheries. *In* T. J. Pitcher, T. Morato, P. J. B. Hart, M. R. Clark, N. Haggan, and R. S. Santos (eds.), Seamounts: Ecology, fisheries, and conservation, p. 296–332. Blackwell Publishing, Oxford.

Fulton, E. A., J. S. Parslow, A. D. M. Smith, and C. R. Johnson. 2004a. Biogeochemical marine ecosystem models 2. The effect of physiological data on model performance. Ecol. Model. 173:371–406.

Fulton, E. A., A. D. M. Smith, and C. R. Johnson. 2003. Effect of complexity on marine ecosystem models. Mar. Ecol. Prog. Ser. 253:1–16.

Fulton, E. A., A. D. M. Smith, and C. R. Johnson. 2004b. Biogeochemical marine ecosystem models I: IGBEM–A model of marine bay ecosystems. Ecol. Model. 174:267–307.

Fulton, E. A., A. D. M. Smith, and C. R. Johnson. 2004c. Effects of spatial resolution on the performance and interpretation of marine ecosystem models. Ecol. Model. 176:27–42.

Fulton, E. A., A. D. M. Smith, and D. C. Smith. 2007b. Alternative management strategies for Southeast Australian Commonwealth Fisheries: Stage 2: Quantitative management strategy evaluation. Australian Fisheries Management Authority. Fisheries Research and Development Corp., Deakin West, ACT.

Galindo-Bect, M. S. 2003. Larvas y postlarvas de camarones peneidos en el alto Golfo de California y capturas de camaron con relacion al flujo del Rio Colorado. Universidad Autonoma de Baja California, Ensenada, BC, Mexico.

Galindo-Bect, M. S., E. P. Glenn, H. M. Page, K. Fitzsimmons, L. A. Galindo-Bect, J. M. Hernandez-Ayon, R. L. Petty, J. Garcia-Hernandez, and D. Moore. 2000. Penaeid shrimp landings in the upper Gulf of California in relation to Colorado River freshwater discharge. Fish. Bull. 98:222–225.

Galindo-Reyes, J. G., V. Fossato, C. Villagrana-Lizarraga, and F. Dolci, 1999. Pesticides in water, sediments, and shrimp from a coastal lagoon off the Gulf of California. Mar. Pol. Bull. 38(9): 837-841.

Gamble, R. Unpubl. manuscr. Atlantis availability parameters GUI user's manual, dated 2007. (Available from R. Gamble, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543.)

Garcia, A. 1991. Spawning stock recruitment relationships of white shrimp in the southwestern Gulf of Mexico. Trans. Am. Fish. Soc. 120:519–527.

García-Juárez,. A. R., G. Rodríguez-Dominguez, and D. B. Lluch-Cota. 2009. Blue shrimp (*Litopenaeus stylirostris*) catch quotas as a management tool in the upper Gulf of California. Cienc. Mar. 35(3):297–306.

Gaxiola-Castro, G., S. Alvarez-Borrego, M. F. Lavín, A. Zirino, and S. Najera-Martinez. 1999. Spatial variability of the photosynthetic parameters and biomass of the Gulf of California phytoplankton. J. Plankton Res. 21:231–245.

Gendron, D. 2002. Ecología poblacional de la ballena azul *Balaenoptera musculus* de la Península de Baja California. Tesis de doctorado. CICESE, Ensenada, BC, Mexico.

Gendron, D., and T. Gerrodette. 2004. Estimaciones de abundancia de ballenas azules en aguas Baja Californianas, a partir de prospecciones aéreas y marítimas. Resúmenes:11ª Reunión de Trabajo de Especialistas en Mamíferos acuáticos de América del Sur. Quito, Ecuador.

Gendron, D., and J. Urbán-Ramírez. 1993. Evidence of feeding by humpback whales (*Megaptera novaeangliae*) in the Baja California breeding ground, Mexico. Mar. Mammal Sci. 9:76–81.

Gendrop-Funes, V., M. J. Acosta-Ruiz, and R. A. Schwartzlose. 1978. Distribución horizontal de clorofila a durante la primavera en la parte norte del Golfo de California. Cienc. Mar. 5:71–89.

Gerhardinger, L. C., M. Hostim-Silva, R. P. Medeiros, J. Matarezi, A. A. Bertoncini, M. O. Freitas, and B. P. Ferreira. 2009. Fishers' resource mapping and goliath grouper *Epinephelus itajara* (Serranidae) conservation in Brazil. Neotrop. Ichthyol. 7:93–102.

Gerrodette, T., L. A. Fleischer, H. Pérez-Cortés, and B. Villa-Ramírez. 1995. Distribution of the vaquita, *Phocoena sinus*, based on sightings from systematic surveys. Rep. International Whaling Commission Special Issue 16:273–282.

Gerrodette, T., and D. M. Palacios. 1996. Estimates of cetacean abundance in EEZ waters of the eastern tropical Pacific. Administrative rep. LJ-96-10. Southwest Fisheries Science Center, La Jolla, CA.

Gilligan, M. R. 1980. The island and mainland biogeography of resident rocky-shore fishes in the Gulf of California. Univ. Arizona, Tucson.

Glenn, E., C. Lee, R. Felger, and S. Zengel. 1996. Effects of water management on the wetlands of the Colorado River delta, Mexico. Conserv. Biol. 10:1175–1186.

Glenn, E. P., P. Nagler, R. Brusca, and O. Hinojosa-Huerta. 2006. Coastal wetlands of the northern Gulf of California: Inventory and conservation status. Aquat. Conserv.: Mar. Freshw. Ecosyst. 16:5–28.

Godley, B. J., D. R. Thompson, S. Waldron, and R. W. Furness. 1998. The trophic status of marine turtles as determined by stable isotope analysis. Mar. Ecol. Prog. Ser. 166:277–284.

Gribble, N. A. 2003. GBR-prawn: Modeling ecosystem impacts of changes in fisheries management of the commercial prawn (shrimp) trawl fishery in the far northern Great Barrier Reef. Fish. Res. 65:493–506.

Grismer, L. L. 2002. Amphibians and reptiles of Baja California, including its Pacific islands and the islands in the Sea of Cortes. University of California Press, Berkeley.

Guerrero-Ruíz, M., J. Urbán-Ramírez, and L. Rojas-Bracho. 2006. Las ballenas del Golfo de California. Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) Instituto Nacional de Ecología (INE).

Hanson, P. C., T. B. Johnson, D. E. Schindler, and J. Kitchell. 1997. Fish Bioenergetics 3.0. Univ. Wisconsin, Sea Grant Institute, Madison.

Hastings, P. A., and L. T. Findley. 2007. Marine fishes of the Upper Gulf Biosphere Reserve, northern Gulf of California. *In* R. S. Felger and B. Broyles (eds.), Dry borders: Great natural areas of the Gran Desierto and upper Gulf of California, p. 799. University of Utah Press, Salt Lake City.

Hearn, A., P. Martinez, M. V. Toral-Granda, J. C. Murillo, and J. J. Polovina. 2005. Population dynamics of the exploited sea cucumber *Isostichopus fuscus* in the western Galapagos Islands, Equador. Fish. Oceanogr. 14:377–385.

Heemstra, P. C. 1995. Serranidae. Meros, serranos, guasetas, enjambres, baquetas, indios, loros, gallinas, cabrillas, garropas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para Identification de Especies para lo Fines de la Pesca. Pacifico Centro-Oriental, p. 1565–1613. FAO, Rome.

Heemstra, P. C., and J. E. Randall. 1993. FAO species catalogue. Vol. 16. Groupers of the world (family Serranidae, subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper, and lyretail species known to date. Fisheries Synopsis 125:382. FAO, Rome.

Hendrickx, M. E. 2007. Biodiversidad y ecosistemas: El caso del Pacífico Mexicano. *In* A. Córdova, F. Rosete-Verges, G. Enríquez, and B. Fernández de la Torre (eds.), Ordenamiento ecológico marino, p. 116–123. Visión temática de la regionalización. SEMARNAT-INE. ISBN: 968-817-807-1.

Hernandez-Becerril, D. U. 1987. Vertical distribution of phytoplankton in the central and northern part of the Gulf of California (June 1982). Mar. Ecol. 8:237–251.

Hernández-Becerril, D. U. 1998. Species of the planktonic diatom genus *Pseudo-nitzschia* of the Pacific coast of Mexico. Hydrobiologia 379:1–3.

Hernández-Becerril, D. U., and M. I. T. Pena. 1995. Planktonic diatoms from the Gulf of California and coasts off Baja California: Species of the genus *Thalassiosira*. Bot. Mar. 38:543–555.

Herrero-Perezrul, M. D., H. R. Bonilla, F. Garcia-Dominguez, and C. E. Cintra-Buenrostro. 1999. Reproduction and growth of *Isostichopus fuscus* (Echinodermata: Holothuroidea) in the southern Gulf of California, Mexico. Mar. Biol. 135:521–532.

Heyning, J. E. 1989. Cuvier's beaked whale, *Ziphius cavirostris*. *In* S. H. Ridgway and S. R. Harrison (eds.), Handbook of marine mammals, River dolphins and the larger toothed whales, p. 289–308. Academic Press, London.

Hidalgo-Gonzáles, R. M., and S. Alvarez-Borrego. 2001. Chlorophyll profiles and the water column structure in the Gulf of California. Oceanol. Acta 24:19–28.

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: Choice, dynamics, and uncertainty. Chapman & Hall, New York.

Holling, C. S. 1959. The components of predation as revealed by a study of small mammal predation of the European pine sawfly. Can. Entomol. 91:293–320.

Holts, D. B. 1988. Review of U.S. West Coast commercial shark fisheries. Mar. Fish. Rev. 50:1–7.

Horne, P. J., I. C. Kaplan, K. N. Marshall, P. S. Levin, C. J. Harvey, L. M. Herman, and E. A. Fulton. 2009. Design and parameterization of a spatially explicit ecosystem model of the central California Current. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-104.

Hu, C., K. L. Carder, and F. Müller-Karger. 2000. Atmospheric correction of SeaWiFS imagery over turbid coastal waters: A practical method. Remote Sens. Environ. 74:195–206.

INAPESCA (Instituto Nacional de Pesca). 2006a. Erizo de mar. *In* P. J. Cuellar and C. O. Cadena, (eds.), Sustentabilidad y Pesca Responsable en Mexico, p. 87–100. Instituto Nacional de Pesca, Santa Cruz Atoyac, Delegación Benito Juárez, 03310 Mexico, DF.

INAPESCA (Instituto Nacional de la Pesca). 2006b. Sustentabilidad y pesca responsable en Mexico; Evaluación y manejo. Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion (SAGARPA), Mexico, DF.

Jackson, J. B. C., M. X. Kirby, W. H. Berger, K. A. Bjorndal, L. W. Botsford, B. J. Bourque, R. H. Bradbury, R. Cooke, J. Erlandson, J. A. Estes, T. P. Hughes, S. Kidwell, C. B. Lange, H. S. Lenihan, J. M. Pandolfi, C. H. Peterson, R. S. Steneck, M. J. Tegner, and R. R. Warner. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293:629–637.

Jaquet, N., and D. Gendron. 2002. Distribution and relative abundance of sperm whales in relation to key environmental features, squid landings, and the distribution of other cetacean species in the Gulf of California, Mexico. Mar. Biol. 141:591–601.

Jaramillo-Legorreta, A., L. Rojas-Bracho, R. L. Brownell, A. J. Read, R. R. Reeves, K. Ralls, and B. L. Taylor. 2007. Saving the vaquita: Immediate action, not more data. Conserv. Biol. 21:1653–1655.

Jaramillo-Legorreta, A., L. Rojas-Bracho, and T. Gerrodette. 1999. A new abundance estimate for vaquitas: First step for recovery. Mar. Mammal Sci. 15:957–973.

Jefferson, T. A., S. Leatherwood, and M. A. Webber. 1993. Marine mammals of the world. U.N. Food and Agriculture Organization species identification guide. FAO, Rome.

Johannes, R. E., M. M. Freeman, and R. J. Hamilton. 2000. Ignore fisher's knowledge and miss the boat. Fish Fish. 1:257–271.

Jørgensen, S. E. 2008. Overview of the model types available for development of ecological models. Ecol. Model. 215:3–9.

Joung, S. J., C. T. Chen, E. Clark, S. Uchida, and W. Y. P. Huang. 1996. The whale shark, *Rhincodon typus*, is a livebearer: 300 embryos found in one "megamamma" supreme. Environ. Biol. Fishes 46:219–223.

Kaplan, I. Unpubl. manuscr. Atlantis preliminary techinical manual, dated 2008. (Available from I. Kaplan, NWFSC, 2725 Montlake Blvd. E., Seattle, WA. 98112.)

Kaplan, I. C., E. A. Fulton, I. Ortiz, and C. H. Ainsworth. Unpubl. manuscr. How to build an Atlantis model: A living document. (Available from I. Kaplan, NWFSC, 2725 Montlake Blvd. E., Seattle, WA 98112.)

Larson, R. J. 1986. Seasonal changes in the standing stocks, growth rates, and production rates of gelatinous predators in Saanich Inlet, British Columbia. Mar. Ecol. Prog. Ser. 33:89–98.

Larson, R. J. 1991. Diet, prey selection, and daily ration of *Stomolophus meleagris*, a filter-feeding scyphomedusa from the NE Gulf of Mexico. Estuar. Coast. Shelf Sci. 32:511–525.

Lavín, M. F., R. Durazo, E. Palacios, M. L. Argote, and L. Carrillo. 1997. Lagrangian observations of the circulation in the northern Gulf of California. J. Phys. Oceanogr. 27:2298–2305.

Lavín, M. F., V. M. Godinez, and L. G. Alvarez. 1998. Inverse-estuarine features of the upper Gulf of California. Estuar. Coast. Shelf Sci. 47:769–795.

Lavín, M. F., and S. Sanchez. 1999. On how the Colorado River affected the hydrography of the upper Gulf of California. Cont. Shelf Res. 19:1545–1560.

Le Boeuf, B. J., D. Aurioles, R. Condit, C. Fox, R. Gisiner, R. Romero, and F. Sinsel. 1982. Size and distribution of the California sea lion population in Mexico. Proc. Calif. Acad. Sci. 43:77–85.

Leatherwood, S., R. R. Reeves, W. Perrin, and K. Evans. 1988. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent Arctic waters: A guide to their identification. Dover Publications, New York.

Lercari, D., and E. A. Chávez. 2007. Possible causes related to historic stock depletion of the totoaba, *Totoaba macdonaldi* (Perciformes: Sciaenidae), endemic to the Gulf of California. Fish. Res. 86:136–142.

Levin, P. S., M. J. Fogarty, S. A. Murawski, and D. Fluharty. 2009. Integrated ecosystem assessments: Developing the scientific basis for ecosystem-based management of the ocean. PLoS Biol 7:e1000014.

Livingston, P. A., and M. S. Alton. 1982. Stomach contents of Pacific whiting, *Merluccius productus*, off Washington and Oregon, April-July 1967. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/NWC-32.

Lluch-Belda, D., and F. J. Magallón-Barajas. 1986. Large fluctuations in the sardine fishery in the Gulf of California: Possible causes. Calif. Coop. Ocean. Fish. Investig. Rep. 27:136–140.

Lluch-Cota, S. E. 2004. Gulf of California. *In* Marine ecosystems of the North Pacific, p. 278. PICES Special Publication. North Pacific Marine Science Organization, Sidney, BC, Canada.

Lluch-Cota, S. E., E. A. Aragón-Noriega, F. Arreguín-Sánchez, D. Aurioles-Gamboa, J. J. Baustista-Romero, R. C. Brusca, R. Cervantes-Durarte, R. Cortés-Altamirano, P. Del-Monte-Luna, A. Esquivel-Herrera, G. Fernández, M. E. Hendrickx, S. Hernández-Vázquez, H. Herrerra-Cervantes, M. Kahru, M. F. Lavín, D. Lluch-Belda, D. B. Lluch-Cota, J. López-Martínez, S. G. Marinone, M. O. Nevárez-Martínez, S. Ortega-García, E. Palacios-Castro, A. Parés-Sierra, G. Ponce-Díaz, M. Ramírez-Rodríguez, C. A. Salinas-Zavala, R. A. Schwartzlose, and A. P. Sierra-Beltrán. 2007. The Gulf of California: Review of ecosystem status and sustainability challenges. Prog. Oceanogr. 73:1–26.

Lopez-Martinez, J., E. A. Chavez, S. Hernandez-Vazquez, and E. Alcantara-Razo. 1999. Potential yield of a rock shrimp stock, *Sicyonia penicillata*, in the northern Gulf of California. Crustaceana 72:581–590.

Lopez-Mendilaharsui, M., S. C. Gardneri, R. Riosmena-Rodriguez, and J. A. Seminoff. 2008. Diet selection by immature green turtles (*Chelonia mydas*) at Bahia Magdalena foraging ground in the Pacific Coast of the Baja California Peninsula, Mexico. J. Mar. Biol. Assoc. UK 88:641–647.

Lora-Vilchis, M. C., and A. N. Maeda-Martinez. 1997. Ingestion and digestion index of catarina scallop *Argopecten ventricosus-circularis*, Sowerby II, 1842, veliger larvae with 10 microalgae species. Aquacult. Res. 28:908–910.

Lozano, H. 2006. Historical ecosystem modeling of the upper Gulf of California (Mexico): Following 50 years of change. Doctoral dissertation. Univ. British Columbia, Vancouver.

Lozano-Alvarez, E., and G. Aramoni-Serrano. 1997. Alimentacion y estado nutricional de las langostas *Panulirus inflatus* y *Panulirus gracilis* (Decapoda: Palinuridae) en Guerrero, Mexico. Rev. Biol. Trop. 44-45:453–461.

Lozano-Montes, H. M., T. J. Pitcher, and N. Haggan. 2008. Shifting environmental and cognitive baselines in the upper Gulf of California. Front. Ecol. Environ. 6:75–80.

Mace, P. M. 2004. In defense of fisheries scientists, single-species models, and other scapegoats: Confronting the real problems. Mar. Ecol. Prog. Ser. 274:285–291.

Mackas, D. L., R. Kieser, M. Saunders, D. R. Yelland, R. M. Brown, and D. F. Moore. 1997. Aggregation of euphausiids and Pacific hake (*Merluccius productus*) along the outer continental shelf off Vancouver Island. Can. J. Fish. Aquat. Sci. 54:2080–2096.

Magallón-Barajas, F. J. 1987. The Pacific shrimp fishery of Mexico. Calif. Coop. Ocean. Fish. Investig. Rep. 28:43–52.

Mangel, M., and P. S. Levin. 2005. Regime, phase, and paradigm shifts: Making community ecology the basic science for fisheries. Philos. T. Roy. Soc. B 360:95–105.

Mangels, K. F., and T. Gerrodette. 1994. Report of cetacean sightings during a marine mammal survey in the eastern Pacific Ocean and the Gulf of California aboard the NOAA ships *McArthur* and *David Starr Jordan*, July 28–November 6, 1993. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-SWFSC-211.

Marshall, K. Unpubl. data. Conversion ratios. (Available from K. Marshall, Colorado State University, 1472 Campus Delivery, Fort Collins, Colorado 80523.)

Martell, S. Unpubl. data. Graphics tracing program. (Available from S. Martell, University of British Columbia Fisheries Centre, 2202 Main Mall, Vancouver, British Columbia V6T 1Z4.)

Martinez-Cordova, L. R., and E. Pena-Messina. 2005. Biotic communities and feeding habits of *Litopenaeus vannamei* (Boone 1931) and *Litopenaeus stylirostris* (Stimpson 1974) in monoculture and polyculture semi-intensive ponds. Aquacult. Res. 36:1075–1084.

Martinez-Cordova, L. R., A. C. Torres, and M. A. Porchas-Cornejo. 2003. Dietary protein level and natural food management in the culture of blue (*Litopenaeus stylirostris*) and white shrimp (*Litopenaeus vannamei*) in microcosms. Aquacult. Nutr. 9:155-160.

Martinez-Fernandez, E., H. Acosta-Salmon, and C. Rangel-Davalos. 2004. Ingestion and digestion of 10 species of microalgae by winged pearl oyster *Pteria sterna* (Gould, 1851) larvae. Aquaculture 230:417–423.

Mateos, E., S. G. Marinone, and A. Pares-Sierra. 2009. Towards the numerical simulation of the summer circulation in Todos Santos Bay, Ensenada, BC, Mexico. Ocean Model. 27(1–2):107–112.

Mellink, E., E. Palacios, and S. González. 1996. Notes on nesting birds of the cienega de Santa Clara saltflat, northwestern Sonora, Mexico. Western Birds 27:207–212.

Mellink, E., E. Palacios, and S. Gonzalez. 1997. Non-breeding water birds of the delta of the Colorado River, Mexico. J. Field Ornithol. 68:113–123.

Meltzer, L., and J. O. Chang. 2006. Export market influence on the development of the Pacific shrimp fishery of Sonora, Mexico. Ocean Coast. Manage. 49:222–235.

Menden-Deuer, S., and E. J. Lessard. 2000. Carbon to volume relationships for dinoflagellates, diatoms, and other protist plankton. Limnol. Oceanogr. 45:569–579.

Mesnick, S. L., M. D. G. Rivas, and B. J. Le Boeuf. 1998. Northern elephant seals in the Gulf of California, Mexico. Mar. Mammal Sci. 14:171–178.

Metcalf, S. J., J. M. Dambacher, A. J. Hobday, and J. M. Lyle. 2008. Importance of trophic information, simplification, and aggregation error in ecosystem models. Mar. Ecol. Prog. Ser. 360:25–36.

Millán-Núñez, E., E. Santamaría-del-Angel, R. Cajal-Medrano, and O. A. Alcides. 1999. The Colorado River delta: A high primary productivity ecosystem. Cienc. Mar. 25:509–524.

Millán-Núñez, R., R. Cajal-Medrano, E. Santamaría-del-Angel, and E. Millán-Núñez. 1993. Primary productivity and chlorophyll *a* in the central part of the Gulf of California (autumn 1987). Cienc. Mar. 19:29–40.

Montgomery, W. L., T. Gerrodette, and L. D. Marshall. 1980. Effects of grazing by the yellowtail surgeonfish, *Prionurus punctatus*, on algal communities in the Gulf of California, Mexico. Bull. Mar. Sci. 30:901–908.

Morales-Bojórquez, E., J. López-Martínez, and S. Hernández-Vázquez. 2001. Dynamic catch-effort model for brown shrimp *Farfantepenaeus californiensis* (Holmes) from the Gulf of California, Mexico. Cienc. Mar. 27(1):105–124.

Morales-Zárate, M. V., F. Arreguín-Sánchez, J. López-Martínez, and S. E. Lluch-Cota. 2004. Ecosystem trophic structure and energy flux in the northern Gulf of California, Mexico. Ecol. Model. 174:331–345.

Moreno-Báez, M. Unpubl. data. Community interview information. (Available from M. Moreno-Báez, University of Arizona, 325 Biological Sciences East, Tucson, AZ 85721).

Moreno-Báez, M., B. J. Orr, R. Cudney-Bueno, and W. Shaw. 2010. Using fishers' local knowledge to aid management at regional scales: Spatial distribution of small-scale fisheries in the northern Gulf of California, Mexico. Bull. Mar. Sci. 86(2):339–353.

Mortimer, J. A., M. Donnelly, and P. T. Plotkin. 2000. Sea turtles. *In* C. R. C. Sheppard (ed.), Seas at the millennium: An environmental evaluation, p. 59–71. Vol. 3: Global issues and processes. Pergamon, Oxford.

Morzaria-Luna, H., and P. Turk-Boyer. 2009. Database of rocky habitats of the northern Gulf of California (Base de Datos de Habitats Rocosos del Norte del Golfo de California). CEDO Intercultural. (Available from CEDO Intercultural, Mexico 638-382-0113, United States 520-320-5473, info@cedointercultural.org.)

Mueller, G. A., and P. C. Marsh. 2002. Lost, a desert river and its native fishes: An historical perspective of the lower Colorado River. Rep. USGS/BRD/ITR-2002-0010. U.S. Geological Survey, Denver, CO.

Murray, A. G., and J. S. Parslow. 1999. Modeling of nutrient impacts in Port Phillip Bay—A semienclosed marine Australian ecosystem. Mar. Freshwater Res. 50:597–611.

Myers, R. A., and B. Worm. 2003. Rapid worldwide depletion of large predatory fish communties. Nature 423:280–283.

Nava-Romo, J. M. 1994. Impactos, a corto y largo plazo, en la diversidad y otras características ecológicas de la comunidad béntico-demersal capturada por la pesquería de camarón en el norte del alto Golfo de California, Mexico. Instituto Technológico y de Estudios Superiores de Moneterrey, Guaymas, Sonora, Mexico.

Nelson, E., E. A. Ramirez-Felix, F. Arenas, B. Carranza, P. Jacquemine, S. Prado, and N. Solis. 1980. Evaluación de los recursos demersales accesibles a redes de arrastre de fondo en el Golfo de California (Mar de Cortés), Mexico, Durante 1979. Programa de Investigación y Desarrollo Pesquero Integrado. Programa de las Naciones Unidas para el Desarrollo. FAO, Mexico.

Nevárez-Martínez, M. O., A. Hernandez-Herrera, E. Morales-Bojorquez, A. Balmori-Ramirez, M. A. Cisneros-Mata, and R. Morales-Azpeitia. 2000. Biomass and distribution of the jumbo squid (*Dosidicus gigas*; d'Orbigny 1835) in the Gulf of California, Mexico. Fish. Res. 49:129–140.

Nevárez-Martínez, M.O., M. Martínez-Zavala, C. E. Cotero-Altamirano, M. L. Jacob-Cervantes, Y. Green-Ruiz, G. Gluyas-Millan, A. Cota-Villavicencio, and J. P. Santos-Molina. 2006. *In* P. J. Cuellar and C. O. Cadena, (eds.), Sustentabilidad y Pesca Responsable en Mexico, p. 265–301. Insituto Nacional de la Pesca. Santa Cruz Atoyac. Delegación Benito Juárez, C.P. 03310, Mexico, DF.

NOAA (National Oceanic and Atmospheric Administration). 2003. New priorities for the twenty-first century: NOAA's strategic plan for FY 2003-2008 and beyond. U.S. Dept. Commerce. Online at http://www.seagrant.noaa.gov/GreenBook/sg_strategic_plan_082304.pdf [accessed 27 September 2010].

Orduña-Rojas, J., and R. M. Longoria-Espinoza. 2006. Metal content in *Ulva lactuca* (Lenaeus) from Navachist Bay (southeast Gulf of California) Sinaloa, Mexico. Bull. Environ. Contam. Toxicol. 77:574–580.

Ortiz, I. Unpubl. data. Siler's competing risk model. (Available from I. Ortiz, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115).

Ortiz-Lozano, L., A. Granados-Barba, V. Solis-Weiss, and M. A. Garcia-Salgado. 2005. Environmental evaluation and development problems of the Mexican Coastal Zone. Ocean Coast. Manage. 48.

Pacheco-Ruíz, I., J. Zertuche-González, F. Correa-Díaz, F. Arellano-Carbajal, and A. Chee-Barragán. 1999. *Gracilariopsis lemaneiformis* beds along the west coast of the Gulf of California, Mexico. Hydrobiologia 399:509–514.

PANGAS (Pesca Artesanal del Norte del Golfo de California–Ambiente y Societad). 2008. Protocolo de monitoreo submarine. PANGAS-PISCO, Univ. Arizona, School of Natural Resources, Tucson.

Paredes, G. Unpubl. data. Dive transect data. (Available from G. Paredes, Scripps Institute of Oceanography, Univ. California San Diego, La Jolla, CA.)

Pares-Sierra, A. Unpubl. data. Nested design submodel. (Available from A. Pares-Sierra, Departamento de Oceanografía Física, CICESE, Km 107 Carretera Tijuana-Ensenada, Ensenada, BC, Mexico 22800.)

Patten, M. A., E. Mellink, H. Gómez de Silva, and T. E. Wurster. 2001. Status and taxonomy of the Colorado desert avifauna of Baja California. Monog. Field Ornithol. 3:29–63.

Paul, R. K. G. 1981. Nature diet, feeding and predatory activity of the crabs *Callinectes arcuatus* and *C. toxotes* (Decapoda, Brachyura, Portunidae). Mar. Ecol. Prog. Ser. 6:91–99.

Pauly, D. 1980. On the interrelationship between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal du Conseil pour l'Exploration de la Mer 39:175–192.

Pauly, D., and V. Christensen. 1995. Primary production required to sustain global fisheries. Nature 374:255–257.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres. 1998. Fishing down marine food webs. Science 279:860–863.

Pauly, D., M. L. Soriano-Bartz, and M. L. D. Palomares. 1993. Improved construction, parameterization, and interpretation of steady-state ecosystem models. *In* V. Christensen and D. Pauly (eds.), Trophic models of aquatic ecosystems, p. 1–13. ICLARM Conference Proceedings, Manila, Philippines.

Pedrín-Osuna, O. A., J. H. Córdova-Murueta, and M. Delgado-Marchena. 2001. Crecimiento y mortalidad de la totoaba, *Totoaba macdonaldi*, del alto Golfo de California. INP-SAGARPA, Mexico. Ciencia Pesquera 14:131–140.

Pegau, W. S., J. R. V. Zaneveld, A. H. Barnard, H. Maske, S. Alvarez-Borrego, R. Lara-Lara, and R. Cervantes-Duarte. 1999. Inherent optical properties in the Gulf of California. Cienc. Mar. 25:469–485.

Penn, J. W., and N. Caputi. 1986. Spawning stock recruitment relationships and environmental influences on the tiger prawn (*Penaeus esculentus*) fishery in Exmouth Gulf, Western Australia. Aust. J. Mar. Fresh. Res. 37:491–505.

Peresbarbosa, E., and E. Mellink. 1994. More records of breeding birds from Montague Island, northern Gulf of California. Western Birds 25:201–203.

Pérez-Cortés, H., and L. Rojas-Bracho. 2000. Mexico progress report on cetacean research, January to December 2000, with statistical data for the calendar year 2000. SC/53/ Prog. Rep. Mexico. International Whaling Commission.

Pérez-Mellado, J. 1980. Análisis de la fauna de acompañamiento del camarón capturado en las costas de Sonora y Sinaloa, Mexico. Master's thesis. Instituto Tecnológico de Estudios Superiores de Monterrey, Sonora, Mexico.

Perez-Valencia, S. Unpubl. data. Active licenses. (Available from S. Perez-Valencia, Centro Intercultural de Estudios de Desiertos y Océanos, A.C., Apartado Postal #53, Puerto Peñasco, Sonora, Mexico 83550.)

Perrin, W., B. Wursig, and H. Thewissen (eds.). 2002. Encyclopedia of marine mammals. Academic Press, San Diego, CA.

Pinnegar, J. K., J. L. Blanchard, S. Mackinson, R. D. Scott, and D. E. Duplisea. 2005. Aggregation and removal of weak-links in food-web models: System stability and recovery from disturbance. Ecol. Model. 184:229–248.

Pitkitch, E. K., C. Santora, E. Babcock, A. Bakun, R. Bonfil, D. O. Conover, P. Dayton, P. Doukakis, D. Fulharty, B. Heneman, E. D. Houde, J. Link, P. A. Livingston, M. Mangel, M. K. McAllister, J. G. Pope, and K. J. Sainsbury. 2004. Ecosystem-based fishery management. Science 305:346–347.

Plagányi, E. E. 2007. Models for an ecosystem approach to fisheries. FAO, Rome.

Polovina, J. J. 1984. Model of a coral reef ecosystem. Coral Reefs 3:1–11.

Ramírez, E. G. 1967. Resumen estadistico de la captura anual de totoaba en el Golfo de California en el periodo 1929–1966. 124 Volumen XIII, Instituto Nacional de Investigaciones Biologico Pesqueras, Secretaria de Industria Y Comercio Direccion General de Pesca e Industrias Conexas, Comision Nacional Consultiva de Pesca, Carmona y Valle 101, 40. Piso, Mexico 7, DF.

Readdie, M. D., M. Ranelletti, and R. M. McCourt. 2006. Common seaweeds of the Gulf of California. Algas comunes del Golfo de California. 1st edition. Sea Challengers, Monterey, CA.

Revelles, M., L. Cardona, A. Aguilar, and G. Fernandez. 2007. The diet of pelagic loggerhead sea turtles (*Caretta caretta*) off the Balearic Archipelago (western Mediterranean): Relevance of long-line baits. J. Mar. Biol. Assoc. UK 87:805–813.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board of Can. 191:1–382.

Robertson, D. R., and G. R. Allen. 2002. Shorefishes of the tropical eastern Pacific: An information system. Smithsonian Tropical Research Institute, Balboa, Panama.

Rodriguez, C. A., K. W. Flessa, and D. L. Dettman. 2001. Effects of upstream diversion of Colorado River water on the estuarine bivalve mollusc *Mulinia coloradoensis*. Conserv. Biol. 15:249–258.

Rodríguez Sánchez, R., S. Hernández-Vázquez, D. Lluch-Belda, R. Félix-Uraga, S. Ortega, A. Villa Arce, G. Ponce-Díaz, and D. B. Lluch-Cota. 1996. Pesquerías de Pelágicos Menores (Sardinas y Anchovetas). *In* M. Casas Valdez and G. Ponce-Díaz (eds.), Estudio del potencial pesquero y acuícola de Baja California Sur. B.C.S. Secretaria de Medio Ambiente y Recursos Naturales y Pesca, La Paz, BCS, Mexico.

Rojas-Bracho, L., R. R. Reeves, and A. Jaramillo-Legorreta. 2006. Conservation of the vaquita *Phocoena sinus*. Mammal Rev. 36:179–216.

Rojas-Bracho, L., R. R. Reeves, A. Jaramillo-Legorreta, and B. L. Taylor. 2007. Vaquita (*Phocoena sinus*). IUCN red list of threatened species. Online at http://www.iucnredlist.org/apps/redlist/details/17028/0 [accessed 27 September 2010].

Rojo, M. Unpubl. manuscr. Sampling protocols. (Available from M. Rojo, Comunidad y Biodiversidad, Boulevard Agua Marina #297 entre Jaiba y Tiburon Colonia Delicias, Guaymas, Sonora 85420 Mexico.)

Rosas-Alayola, J., A. Hernandez-Herrera, F. Galvan-Magana, L. A. Abitia-Cardenas, and A. F. Muhlia-Melo. 2002. Diet composition of sailfish (*Istiophorus platypterus*) from the southern Gulf of California, Mexico. Fish. Res. 57:185–195.

Rosas-Luis, R., C. A. Salinas-Zavala, V. Koch, and P. Del Monte Luna. 2008. Importance of jumbo squid *Dosidicus gigas* (Orbigny 1835) in the pelagic ecosystem of the central Gulf of California. Ecol. Model. 218:149–161.

Rowell, K., K. W. Flessa, D. L. Dettman, M. Román, L. R. Gerber, and L. T. Findley. 2008. Diverting the Colorado River leads to a dramatic life history shift in an endangered marine fish. Biol. Conserv. 141:1138–1148.

Ruiz-Luna, A., R. Meraz-Sanchez, and J. Madrid-Vera. 2010. Estimating abundance distribution patterns of commercial shrimp off northwestern Mexico using geographic information systems. Cienc. Mar. 36(2):107–120.

SAGARPA (Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion [Secretary of Agriculture, Ranching, Rural Development, Fisheries, and Food Supply]). 2002. Anuario estadistico de pesca 2002. Online at http://www.conapesca.gob.mx/wb/ [accessed 27 September 2010].

Sainsbury, K. J., A. E. Punt, and A. D. M. Smith. 2000. Design of operational management strategies for achieving fishery ecosystem objectives. ICES J. Mar. Sci. 57:731–741.

Sala, E., O. Aburto-Oropeza, M. Reza, G. Paredes, and L. G. Lopez-Lemus. 2004. Fishing down coastal food webs in the Gulf of California. Fisheries 29:19–25.

Santamaría-del-Angel, E., S. Alvarez-Borrego, and F. E. Müller-Karger. 1994. Gulf of California biogeographic regions based on coastal zone color scanner imagery. J. Geophys. Res. 99:7411–7421.

Saucedo, P., and M. Monteforte. 1998. Changes in shell dimensions of pearl oysters, *Pinctada mazatlanica* (Hanley 1956) and *Pteria sterna* (Gould 1851) during growth as criteria for Mabe pearl implants. Aquacult. Res. 29:801–814.

SEMARNAT (Secretaria de Medio Ambiente y Recursos Naturales [Secretary of Environment and Natural Resources]). 1995. Programa de manego. Áreas Naturales Protegidas 1. Reserva de la Biósfera del Alto Golfo de California y Delta del Río Colorado. SEMARNAT, Mexico City, DF.

SEMARNAT (Secretaria de Medio Ambiente y Recursos Naturales [Secretary of Environment and Natural Resources]). 2003. Programa de conservación y manejo. Reserva de la Biosfera Alto Golfo de California y Delta del Río Colorado. SEMARNAT, Mexico City, DF.

Seminoff, J. A., and W. J. Nichols. 2006. Sea turtles of the alto golfo: A struggle for survival. *In* R. Felger and B. Broyles (eds.), Dry borders: Great natural reserves of the Sonoran desert, p. 505–729. University of Utah Press, Salt Lake City.

Shenker, J. M. 1984. Scyphomedusae in surface waters near the Oregon coast, May-August, 1981. Estuar. Coast. Shelf Sci. 19:619–632.

Silber, G. 1988. Recent sightings of the Gulf of California harbor porpoise, *Phocoena sinus*. J. Mammal. 69:430–433.

Silber, G. K., M. W. Newcomer, P. C. Silber, H. Perezcortes, and G. M. Ellis. 1994. Cetaceans of the northern Gulf of California—Distribution, occurrence, and relative abundance. Mar. Mammal Sci. 10:283–298.

Sissenwine, M. P. 1978. Is MSY an adequate foundation for optimum yield? Fisheries 3:22–42.

Smiles, M. C. J., and W. G. Pearcy. 1971. Size structure and growth rate of *Euphausia pacifica* off the Oregon coast. Fish. Bull. 69:79–86.

Smith, R. D., J. K. Dukowicz, and R. C. Malone. 1992. Parallel ocean general circulation modeling. Physica D 60:38–61.

Smith, W. H. F., and D. T. Sandwell. 1997. Global sea floor topography from satellite altimetry and ship depth soundings. Science 277:1957–1962.

Song, Y., and D. Haidvogel. 1994. A semi-implicit ocean circulation model using a generalized topography-following coordinate system. J. Comput. Physics 115:228–244.

Sonora. 2008a. INEGI y Gobierno del Estado de Sonora, Anuario Estadístico de Sonora. Secretaria de Economia. Puerto Peñasco: Basic information. Online at http://www.1economiasonora.gob.mx /files_estadistica/perfiles_english/Socieconomic%20Overview%20PUERTO%20PENASCO.pdf [accessed 27 September 2010].

Sonora. 2008b. INEGI y Gobierno del Estado de Sonora, Anuario Estadístico de Sonora. Secretaria de Economia. San Felipe de Jesus: Basic information. Online at http://www.1economiasonora.gob .mx/files_estadistica/perfiles_english/Socieconomic%20Overview%20SAN%20FELIPE%20DE %20JESUS.pdf [accessed 27 September 2010].

Soto-Mardones, L., S. G. Marinone, and A. Parés-Sierra. 1999. Time and spatial variability of sea surface temperature in the Gulf of California. Cienc. Mar. 25:1–30.

Stevens, J. D. 2006. Whale shark (*Rhincodon typus*) biology and ecology: A review of the primary literature. Fish. Res. 84:4–9.

Tershy, B. R., D. Breese, and S. Alvarez-Borrego. 1991. Increase in cetacean and seabird numbers in the Canal De Ballenas during an El Nino southern oscillation event. Mar. Ecol. Prog. Ser. 69:299–302.

Thomson, D. A., L. T. Findley, and A. N. Kerstitch. 2000. Reef fishes of the Sea of Cortez. The rocky-shore fishes of the Gulf of California. University of Texas Press, Austin.

Thomson, D. A., and S. L. Mesnick. 1993. Biodiversity of the marine fauna of the islands in the Gulf of California: Cruise report of an expedition of the marine ecology course of the University of Arizona on the Baja treasure to islands in the Gulf of California, 3–23 July 1993. Univ. Arizona, Tucson.

Thomson, D. A., S. L. Mesnick, and D. J. Schwindt. 1996. Human impact and biodiversity of islands in the Gulf of California. Cruise report of an expedition of the 1994 University of Arizona marine ecology course, 9–30 July 1994. Univ. Arizona, Dept. Ecology and Evolutionary Biology, Tucson.

Thunell, R., C. Pride, P. Ziveri, F. Muller-Karger, C. Sancetta, and D. Murray. 1996. Plankton response to physical forcing in the Gulf of California. J. Plankton Res. 18:2017–2026.

Toral-Granda, M. V. 1996. Biologıa reproductiva del pepino de mar *Isostichopus fuscus* en la Isla Caamano, Santa Cruz, Galapagos. Universidad del Azuay, Cuenca, Ecuador.

Torre, J. Unpubl. data. Fisheries information brochures. (Available from J. Torre, Comunidad y Biodiversidad, Boulevard Agua Marina #297 entre Jaiba y Tiburon Colonia Delicias, Guaymas, Sonora, Mexico 85420.)

Torre, J., and M. Rojo. Unpubl. data. Fishery log books. (Available from J. Torre and M. Rojo, Comunidad y Biodiversidad, Boulevard Agua Marina #297 entre Jaiba y Tiburon Colonia Delicias,Guaymas, Sonora, Mexico 85420.)

Trites, A., and D. Pauly. 1998. Estimating mean body masses of marine mammals from maximum body lengths. Can. J. Zool. 76:886–896.

Turk-Boyer, P. Unpubl. data. Small-scale fisheries. (Available from P. Turk-Boyer, Centro Intercultural de Estudios de Desiertos y Océanos, A.C., Apartado Postal #53, Puerto Peñasco, Sonora, Mexico 83550.)

Turner, R. M., and M. M. Kapiscak. 1980. Recent vegetation changes along the Colorado River between Glen Canyon Dam and Lake Mead, Arizona. U.S. Geol. Surv. Prof. Pap. 1132:125.

Turvey, S. T., L. A. Barrett, H. Yujiang, Z. Lei, Z. Xinqiao, W. Xianyan, H. Yadong, Z. Kaiya, T. Hart, and W. Ding. 2010. Rapid shifting baselines in Yangtze fishing communities and local memory of extinct species. Conserv. Biol. 24(3):778–787.

U.S. Bureau of Reclamation. 2008. Final environmental assessment and finding of no significant impact: Experimental releases from Glen Canyon Dam, Arizona 2008 through 2012. U.S. Dept. Interior. Online at http://www.usbr.gov/uc/envdocs/ea/gc/2008hfe/index.html [accessed 27 September 2010].

U.S. Bureau of Reclamation. 2008. Law of the river. U.S. Dept. Interior, Boulder City, NV. Online at http://www.usbr.gov/lc/region/g1000/lawofrvr.html [accessed 27 September 2010].

U.S. Census Bureau. 2005. Population division, interim state population projections: Total population for regions, divisions, and states 2000 to 2030. Online at http://www.census.gov/population/www/projections/projectionsagesex.html [accessed 18 May 2011].

U.S. Commission on Ocean Policy. 2004. An ocean blueprint for the 21st century. U.S. Commission on Ocean Policy, Washington, DC. Online at http://www.oceancommission.gov/documents/full_color_rpt/000_ocean_full_report.pdf [accessed 27 September 2010].

Urbán-Ramírez, J. 2002. Marine mammals in the Gulf of California: Conservation and management. *In* Back to the future in the Sea of Cortez: A workshop on the restoration of past ecosystems as policy goals for fisheries. CICIMAR, La Paz, BC, Mexico.

Urbán-Ramírez, J., I. Rojas-Bracho, M. Guerrero-Ruíz, A. Jaramillo-Legorreta, and L. T. Findley. 2005. Cetacean diversity and conservation in the Gulf of California. *In* J. L. Cartron, G. Ceballos, and R. Felger (eds.), Biodiversity, ecosystems, and conservation in northern Mexico, 1st edition, p. 276–297. Oxford University Press, New York.

USDI (U.S. Department of the Interior). 2008. Final environmental assessment: Experimental releases from Glen Canyon Dam, Arizona 2008 through 2012. *In* U.S. Dept. Interior, Reclamation: Managing water in the west, p. 60. U.S. Dept. Interior, Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah.

Valdez-Holguín, J. E. 1986. Distribución de la biomamasa y productividad del fitoplancton en el Golfo de California durante el evento de El Niño 1982–1983. Master's thesis. Centro de Investigacion Cientifica y de Educacion Superior de Ensenada, Ensenada, BC, Mexico.

Valdéz-Ornelas, V. M., and E. Torreblanca. Unpubl. data. Catch trends. (Available from V. M. Valdéz-Ornelas and E. Torreblanca, Pronatura Noroeste A.C., Calle Décima No 60, Zona Centro, Ensenada, Baja California, CP 22800, Mexico.)

Van Andel, T. H. 1964. Recent marine sediments of the Gulf of California. *In* T. J. Van Andel and G. G. Shor (eds.), Marine geology of the Gulf of California: A symposium. Am. Assoc. Pet. Geol. Mem. 3:216–310.

Vázquez, M. E. 1997. Distribución espacio-temporal, fidelidad al área y tamaño poblacional del calderón de aletas cortas *Globicephala macrorhynchus* (Gray 1846) en la Bahía de La Paz, B.C.S., Mexico (1989–1995). Tesis de Licenciatura. Universidad Autónoma de Baja California Sur, La Paz, BCS, Mexico.

Vega-Velásquez, A. 2006. Langosta de la Península de Baja California. *In* P. J. Cuellar and C. O. Cadena, (eds.), Sustentabilidad y Pesca Responsable en Mexico, p. 157–210. Insituto Nacional de la Pesca. Santa Cruz Atoyac. Delegación Benito Juárez, C.P. 03310, Mexico, DF.

Velarde, E., and D. W. Anderson. 1994. Conservation and management of seabird islands in the Gulf of California: Setbacks and successes. *In* D. N. Nettleship, J. Burger, and M. Gochfeld (eds.), Seabirds on islands: Threats, case studies, and action plans. Proceedings of the Seabird Specialist Group Workshop held at the XX World Conference of the International Council for Bird Preservation, University of Waikato, Hamilton, New Zealand. Birdlife Conservation Series 1:229–243.

Vidal, O. 1993. Aquatic mammal conservation in Latin America: Problems and perspectives. Conserv. Biol. 7:788–795.

Vieyra, L., E. Velarde, and E. Ezcurra. 2009. Effects of parental age and food availability on the reproductive success of Heermanns's gulls in the Gulf of California. Ecology 90:1084–1094.

Vörös, L., and J. Padisak. 1991. Phytoplankton biomass and chorophyll *a* in some shallow lakes in central Europe. Hydrobiologia 215:111–119.

Walters, C., V. Christensen, S. Martell, and J. Kitchell. 2005. Possible ecosystem impacts of applying MSY policies from single-species assessment. ICES J. Mar. Sci. 62:558–568.

Walters, C., V. Christensen, and D. Pauly. 1997. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. Rev. Fish Biol. Fish. 7:139–172.

Weller, D. W., B. Würsig, and A. L. Bradford. 1999. Gray whales (*Eschrichtius robustus*) off Sakhalin Island, Russia: Seasonal and annual patterns of occurrence. Mar. Mammal Sci. 15:1208–1227.

Wood, J., and C. Day. 2008. CephBase. National Resource Center for Cephalopods. Univ. Texas Medical Branch, Galveston. Online at http://www.gulfbase.org/organization/view.php?oid=nrcc [accessed 27 September 2010].

WWF (World Wildlife Federation). 2008. Vaquita species fact sheet. World Wildlife Federation. Online at http://www.panda.org/what_we_do/endangered_species/cetaceans/about/vaquita/ [accessed 27 September 2010].

Young, R. E. 1978. Vertical distribution and photosensitive vesicles of pelagic cephalopods from Hawaiian waters. Fish. Bull. 76:583–615.

Zavala-Gonzalez, A., and E. Mellink. 1997. Entanglement of California sea lions, *Zalophus californianus californianus*, in fishing gear in the central-northern part of the Gulf of California, Mexico. Fish. Bull. 95:180–184.

Zetina-Rejón, M., F. Arreguín-Sánchez, and E. A. Chavez. 2004. Exploration of harvesting strategies for the management of a Mexican coastal lagoon fishery. Ecol. Model. 172:361–372.

Zhang, C., C. Hu, S. Shang, F. Müller-Karger, Y. Li, M. Dai, B. Huang, X. Ning, and H. Hong. 2006. Bridging between SeaWiFS and MODIS for continuity of chlorophyll *a* concentration assessments off southeastern China. Remote Sens. Environ. 102:250–263.

Appendix A: Functional Group Information

This appendix contains the following tables:

Table A-1. Atlantis fish functional group species composition. Species listed in Table A-4.

Atlantis code	No. of species	Group name (English)	Group name (Spanish)	Group reference	Rationale	Composition
FBP	1	Gulf coney	Baqueta	R. Cudney-Bueno	PANGAS species of interest	*Epinephelus acanthistius*
FDB	2	Extranjero	Extranjero	R. Cudney-Bueno	PANGAS species of interest	*Paralabrax auroguttatus; P. loro*
FDC	1	Leopard grouper	Cabrilla sardinera	R. Cudney-Bueno	PANGAS species of interest	*Mytoperca rosacea*
FDD	1	Gulf grouper	Baya	R. Cudney-Bueno	PANGAS species of interest	*Myctoperca jordani*
FDE	1	Amarillo snapper	Pargo amarilo	R. Cudney-Bueno	PANGAS species of interest	*Lutjanus argentiventris*
FDF	1	Barred pargo	Pargo coconaco	R. Cudney-Bueno	PANGAS species of interest	*Hoplopagrus guentherii*
FDM	35	Groupers and snappers	Mero y pargo	This manuscript	Aggregate group	Groupers (Serranidae) and snappers (Lutjanidae)
FDO	29	Drums and croakers	Chano	S. Perez-Vaecia, pers. commun.	Important pangas boat commercial fish from interviews	Drums and croakers (Sciaenidae)
FDP	16	Grunts	Chicharro	Lozano 2006	High biomass	Grunts (Haemulidae)
FDS	14	Herbivorous fish	Peces herbivoros	This manuscript	Ecological importance	Parrotfishes (Scaridae) and herbivorous species from other families. Herbivory was determined based on the “mainfood” and “herbivory2” fields of the FishBase Ecology table, see appendix tables for references.
FMM	58	Large reef fish	Peces arrecifales menores	This manuscript; S. Perez-Vaecia, pers. commun.	Aggregate group	Surgeonfishes (Acanthuridae) (not elsewhere included), rooster fish (papagallo) (*Nematistius pectoralis*), wrasses (Labridae), triggerfishes (Balistidae), oarfishes (Regalecidae)

Table A-1 continued. Atlantis fish functional group species composition. Species listed in Table A-4.

Atlantis code	No. of species	Group name (English)	Group name (Spanish)	Group reference	Rationale	Composition
FMN	106	Small reef fish	Peces arrecifales menores	This manuscript	Aggregate group (hard substrate)	Porcupine fish (Diodontidae), pufferfish (Tetraodontidae) including bullseye pufferfish (*Sphoeroides annulatus*) (botete) (important trawler commercial fish from interviews), trunkfish (Ostraciidae), filefish (Monacanthidae), Moorish idol (Zanclidae), gobies (Gobiidae), blennies (Blennidae), tube blennies (Chaenopsidae), clinid blennies (Labrisomidae), triplefin blennies (Tripterygiidae), jawfishes (Opistognathidae), hawkfish (Cirrhitidae), damselfish (Pomacentridae), angelfish (Pomacanthidae), butterflyfish (Chaetodontidae), spadefish (Ephippidae), sea chubs (Kyphosidae), goatfish (Mullidae), porgies (Sparidae), tilefish (Malacanthidae), cardinalfish (Apogonidae), soapfish (Grammistidae), cornetfish (Fistulariidae), trumpetfish (Aulostomidae), squirrelfish (Holocentridae), needlefish (Belonidae), frogfish (Antennariidae), lizardfish (Synodontidae), bigeyes (Priacanthidae), snake eels (Ophichthidae), clingfish (Gobiesocidae), flagfins (Aulopidae), snailfish (Liparidae), snooks (Centropomidae), brotula (Bythitidae), toadfish (Batrachoididae), sea catfish (Ariidae), morays (Muraenidae). Species occuring on hard bottom only (see next comment).
FPL	130	Small demersal fish	Peces demersales menores	This manuscript	Aggregate group (soft substrate)	Same families as small reef fish; sorted at species level to include fish occuring on soft substrate (sand and mud). Substrate determined preferentially based on habitat fields of the FishBase Ecology table (i.e., soft, rocky, coral reefs, soft bottom, and hard bottom) and then by the Demers Pelag field of the Species table.
FPS	1	Pacific angel shark	Angelito	R. Cudney-Bueno	PANGAS species of interest	*Squatina californica*
FPO	4	Small migratory sharks	Tiburón tripa	S. Perez-Vaecia, pers. commun.	Important pangas boat commercial fish from interviews	Smoothhounds (genus *Mustelus* spp.) (Triakidae)
FVB	14	Large pelagic sharks	Tiburones pelágicos grandes	This manuscript	Aggregate group	Superorder Selachimorpha
FVD	5	Guitarfish	Guitarra	R. Cudney-Bueno	PANGAS species of interest	Guitarfishes (Rhinobatidae)

Table A-1 continued. Atlantis fish functional group species composition. Species listed in Table A-4.

Atlantis code	No. of species	Group name (English)	Group name (Spanish)	Group reference	Rationale	Composition
FVO	23	Skates, rays, sharks	Rayas, mantas, y tiburones	S. Perez-Vaecia, pers. commun.	Aggregate group/ important pangas boat commercial fish from interviews	Superorder Batoidea (not elsewhere included) (i.e., stingrays, skates, electric rays, sawfish). Important members: butterfly ray (*Gymnura marmorata*) and diamond stingray (*Dasyatis dipterura*)
FVS	33	Flatfish	Lenguado	S. Perez-Vaecia, pers. commun.	Important pangas boat commercial fish from interviews	Righteye flounders (Pleuronectidae), lefteye flounders (Bothidae), large-tooth flounders (Paralichthyidae)
FVT	6	Mojarra	Mojarra	Lozano 2006	High biomass	Mojarras (Gerreidae)
FVV	14	Scorpionfish		Arreguin-Sanchez 2002	Commercial group	Scorpionfishes (Scorpaenidae) and sea robins (Triglidae)
SHB	9	Lanternfish and deep	Mictófidos	Arreguin-Sanchez 2002; Lozano 2006	Commercial group	Lanternfishes (Myctophidae)
SHC	1	Totoaba	Totoaba	This manuscript	Historical and reconstruction interest	*Totoaba macdonaldi*
SHD	37	Large pelagics	Pelágicos mayores	This manuscript	Aggregate group	Large pelagics (not elsewhere included), barracuda (Sphyraenidae), jacks/pomano (Carangidae), machetes (Elopidae), marlin and sailfish (Istiophoridae), swordfish (*Xiaphias gladius*) (Xiphiidae), butterfish (Stromateidae), opah (Lamprididae)
SHP	5	Mackerel	Sierra	S. Perez-Vaecia, pers. commun.	Important pangas boat commerical fish from interviews	Mackerels (*Scomberomorus* spp.) (Scombridae)
SHR	2	Hake	Merluza	S. Perez-Vaecia, pers. commun.	Important trawler commerical fish from interviews	Hakes (*Merluccius* spp.) (Merlucciidae)
SSK	27	Small pelagics	Pelágicos menores	This manuscript	Aggregate group	Herring, sardines, pilchards, sprats (Clupeidae); smelts (Osmeridae), anchovy (Engraulidae), silversides (Atherinopsidae), flying fishes (Exocoetidae)
WHB	5	Mysticeti	Misticetos	Arreguin-Sanchez et al. 2004	Ecological role/conservation	Bryde's whale (*Balaenoptera edeni*), fin whale (*B. physalus*), blue whale (*B. musculus*), gray whale (*Eschrichtius robustus*), humpback whale (*Megaptera novaeangliae*)

Table A-1 continued. Atlantis fish functional group species composition. Species listed in Table A-4.

Atlantis code	No. of species	Group name (English)	Group name (Spanish)	Group reference	Rationale	Composition
WHT	9	Odontocetae	Odontocetos	Lozano 2006	Ecological role/conservation	Long-beaked common dolphin (*Delphinus capensis*), common dolphin (*D. delphis*), bottlenose dolphin (*Tursiops truncatus*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), Baird's beaked whale (*Berardius bairdii*). Also included in this group are sperm whale (*Physeter macrocephalus*), short-fin pilot whale (*Globicephala macrorhynchus*), and false killer whale (*Pseudorca crassidens*). The pygmy beaked whale (*Mesoplodon peruvianus*) may also be present in the northern Gulf of California.
WHS	1	Orca	Orcas	This manuscript	Ecological role/conservation	Orca (*Orcinus orca*)
WDG	1	Vaquita	Vaquita	This manuscript	Conservation	Vaquita (*Phocoena sinus*)
PIN	2	Pinnipeds	Pinípedos	This manuscript	Ecological role/conservation	Elephant seal (*Mirounga angustirostris*), California sea lion (*Zalophus californianus*)
SP	2	Oceanic sea turtles	Tortugas marinas oceánicas	This manuscript	Conservation	Leatherback turtle (*Dermochelys coriacea*), olive Ridley turtle (*Lepidochelys olivacea*)
REP	3	Reef associated turtles	Tortugas arrecifales	This manuscript	Ecological role/conservation	Loggerhead turtle (*Caretta caretta*), hawksbill turtle (*Eretmochelys imbricata*), green turtle (*Chelonia mydas*)
SB	26	Sea birds	Aves marinas	This manuscript	Conservation	Sulidae: blue-footed booby (*Sula nebouxii*), brown booby (*S. leucogaster*). Laridae: Heerman's gull (*Larus heermanni*), California gull (*L. californicus*), yellow-footed gull (*L. livens*). Sternidae: elegant tern (*Thalasseus elegans*), royal tern (*T. maximus*), Forster's tern (*Sterna forsteri*). Hydrobatidae: black storm-petral (*Oceanodroma melania*), least storm-petral (*Halocyptena microsoma*). Phalacrocoracidae: Brandt's cormorant (*Phalacrocorax penicillatus*), double-crested cormorant (*P. auritus*). Fregatidae: magnificent frigatebird (*Fregata magnificens*). Haematopodidae: American oystercatcher (*Haematopus palliatus)*. Ardeidae: snowy egret (*Egretta thula)*, reddish egret (*E. rufescens)*, great egret (*Ardea alba)*, great blue heron (*A. herodias)*. Scolopacidae: whimbrel (*Numenius phaeopus*), least sandpiper (*Calidris minutilla*), black turnstone (*Arenaria melanocephala*). Pelecanidae: brown pelican (*Pelecanus occidentalis)*. Procellariidae: sooty shearwater (*Puffinus griseus)*, flesh-footed shearwater (*P. carneipes)*. Podicipedidae: eared grebe (*Podiceps nigricollis)*. Alcidae: Craveri's murrelet (*Synthliboramphus craveri*).

Table A-1 continued. Atlantis fish functional group species composition. Species listed in Table A-4.

Atlantis code	No. of species	Group name (English)	Group name (Spanish)	Group reference	Rationale	Composition
BB	—	Benthic bacteria	Bacteria bentónica	Fulton et al. 2004a	Ecological role	Heterotrophic eubacteria
BC	6	Scallops and penshells	Callo y almejas	R. Cudney-Bueno	PANGAS species of interest	Callo de escarlopa (*Spondylus calcifer*), Callo mechudo (*S. princeps*), Callo de árbol (*Pteria sterna*), Callo de hacha (*Pinna rugosa*), Callo de riñón (*Atrina tuberculosa*), Madreperla (*Pinctada mazatlanica*)
BD	5	Penaeid shrimp	Camarón peneido	This manuscript	Fishery	Family Penaeidae NEI (except *Litopenaeus stylirostris*); includes brown shrimp (*Penaeus aztecus*), pink shrimp (*P. duorarum*), white shrimp (*P. setiferus*) and rock shrimp (*Sicyonia penicillata*)
BFD	42	Sea cucumbers	Pepino de mar	R. Cudney-Bueno	PANGAS species of interest	Class Holothuroidea
BFF	342	Sessile invertebrates	Invertebrados sésiles	This manuscript	Ecological role/fishery	Phylum Porifera (sponges), Phylum Bryozoa (bryozoans), Phylum Cnidaria NEI (except Scyphozoa), including Class Hydrozoa, Class Anthozoa (anemones, corals, gorgonians), Subphylum Urochordata (tunicates), Phylum Arthropoda Class Maxillopoda NEI (except Subclass copepoda)
BFS	242	Crabs and lobsters	Jaiba y langosta	R. Cudney-Bueno	PANGAS species of interest	Order Decapoda NEI (except shrimp/prawn families and crabs <5 cm); Stomatopods (mantis shrimp)
BG	39	Herbivorous echinoderms	Equinodermos herbívoros	This manuscript	Ecological role	Phylum Echinodermata NEI (except Asteroidea, Echinoidea, and Holothuroidea)
BMD	300	Carnivorous macrobenthos	Macrobentos carnóvoro	This manuscript	Aggregate group	Epifaunal carnivorous invertebrates >5 cm: Class Gastropoda Order Nudibranchia (nudibranchs), Class Polyplacophora (chitons), Class Asteroidea (sea stars) (NB: includes corallivorous Acanthaster spp.), Class Ophiuroidea (brittle stars), Class Cephalopoda Order Octopoda (Octopus), shrimp families >5 cm NEI (except Penaeidae)
BML	863	Infaunal epifaunal meiobenthos	Meiobentos, infauna y epifauna	This manuscript	Aggregate group	Benthic invertebrates <5 cm, Phylum Mollusca Subphylum Crustacea, Class Scaphopoda (tusk shells), Class Malacostraca Order Cumacea (hooded shrimp), Order Isopoda (isopods), Order Amphipoda (amphipods), (NB: small shrimp families) Order Decapoda Family Palaemonidae (anenome shrimp), Family Porcellanidae (porcelain crabs), Family Stenopodidae (coral shrimps); Phylum Nemertea (ribbon worms), Phylum Annelida (segmented worms), Phylum Platyhelminthes (flatworms), Phylum Chaetognatha (arrow worms), Phylum Echiura (spoon worms), Phylum Hemichordata (acorn worms), Phylum Sipuncula (peanut worms)
BMS	416	Bivalves	Bivalvos	This manuscript	Fishery	Semisessile filter feeders: Phylum Mollusca Class Pelecypoda (Bivalvia)

Table A-1 continued. Atlantis fish functional group species composition. Species listed in Table A-4.

Atlantis code	No. of species	Group name (English)	Group name (Spanish)	Group reference	Rationale	Composition
BO	1,111	Snails	Caracol	R. Cudney-Bueno	PANGAS species of interest	Class Gastropoda
CEP	2	Ad. blue crab	Jaiba azul adultos	R. Cudney-Bueno	PANGAS species of interest	*Callinectes bellicosus, C. arcuatus*
(CEP)	(2)	J. blue crab	Jaiba azul juveniles	R. Cudney-Bueno	PANGAS species of interest	*Callinectes bellicosus, C. arcuatus*
DL	N/A	Labile detritus	Detrito lábil	Fulton et al. 2004a	Atlantis requirement /ecological role	Non-living matter (decaying/disassociated)
DR	N/A	Refractory detritus	Detrito refractorio	Fulton et al. 2004a	Atlantis requirement /ecological role	Non-living matter (cohesive)
MA	140*	Macroalgae	Macroalgas	Fulton et al. 2004a, Pacheco-Ruíz et al. 1999, Aguilar-Rosas et al. 2000	Atlantis requirement /basal species	Phylum Chlorophyta (green algae), Phylum Rhodophyta (red algae), Phylum Heterokontophyta Class Phaeophyceae (brown algae)
PB	—	Pelagic bacteria	Bacterias pelágocas	Fulton et al. 2004a	Ecological role	Heterotrophic eubacteria
PL	22*	Large phytoplankton	Fitoplancton grande	Hernández-Becerril and Pena 1995, Hernández-Becerril 1998	Atlantis requirement /basal species	Planktonic diatoms
PS	—	Small phytoplankton	Fitoplancton chico	Fulton et al. 2004a	Atlantis requirement /basal species	Protozoans, Phylum Cyanophyta (blue-green algae), Phylum Dinoflagellata, Phylum Chlorophyta
PWN	1	Ad. blue shrimp	Camarón azul adulto	This manuscript	Fishery	*Litopenaeus stylirostris*
(PWN)	(1)	J. blue shrimp	Camarón azul juvenil	This manuscript	Fishery	*Litopenaeus stylirostris*
SG	—	Seagrass	Pasto marino	Fulton et al. 2004a	Atlantis requirement /basal species	Obligate halophile vascular autotrophs
ZG	104	Jellyfish	Medusas	This manuscript	Ecological role	Class Hydrazoa Order Chondrophora, Order Filifera, Order Hydroida, Order Siphonophora, Class Scyphozoa, Phylum Ctenophora
ZL	15	Large zooplankton	Zooplancton grande	This manuscript	Ecological role	Soft bodied pelagic macroinvertebrates: Phylum Chordata (salps), Class Malacostraca Order Amphipoda, Order Mysida, Order Euphausiacea, Chaetognatha
ZM	4	Squid	Calamar	This manuscript	Fishery	Order Teuthoidea
ZS	—	Small zooplankton	Zooplancton chico	This manuscript	Ecological role	Class Maxillopoda, Subclass Copepoda

Table A-1 continued. Atlantis fish functional group species composition. Species listed in Table A-4.

Atlantis code	No. of species	Group name (English)	Group name (Spanish)	Group reference	Rationale	Composition
MB	—	Microphytobenthos	Microfitobentos	Fulton et al. 2004a	Atlantis requirement /basal species	Phylum Cyanophyta (blue-green algae), Phylum Chlorophyta (green algae), Phylum Rhodophyta (red algae), Phylum Heterokontophyta Class Phaeophyceae (brown algae), Class Bacillariophyceae (diatoms)
DC	NA	Carrion detritus	Detrito carroña (o detrito muerto)	Fulton et al. 2004a	Atlantis requirement /ecological role	Non-living matter (large particles)

Table A-2. Taxonomic organization of invertebrate functional groups.

Phylum	Class	Order	Family	Name	Functional group	No. of species
Annelida				Segmented worms	Infaunal epifaunal meiobenthos	502
Arthropoda	Malacostraca	Stomatopoda		Mantis shrimp	Crabs and lobsters	17
		Amphipoda		Amphipods	Infaunal epifaunal meiobenthos	162
		Cumacea		Hooded shrimp	Infaunal epifaunal meiobenthos	8
		Isopoda		Isopods	Infaunal epifaunal meiobenthos	69
		Tanaidacea		Tanaids	Carnivorous macrobenthos	2
		Euphausiacea		Krill	Large zooplankton	6
		Mysida		Mysids	Large zooplankton	2
		Decapoda	Alpheidae	Snapping shrimps	Carnivorous macrobenthos	40
			Axiidae	Thalassinidean shrimps	Carnivorous macrobenthos	3
			Callianideidae	Shrimps	Carnivorous macrobenthos	1
			Crangonidae	Shrimps	Carnivorous macrobenthos	3
			Gnathophyllidae	Bumblebee shrimps	Carnivorous macrobenthos	1
			Hippolytidae	Broken-back shrimps	Carnivorous macrobenthos	13
			Laomediidae	Thalassinidean shrimps	Carnivorous macrobenthos	1
			Luciferidae	Lucifer prawns	Carnivorous macrobenthos	1
			Oplophoridae	Deepsea shrimps	Carnivorous macrobenthos	1
			Pandalidae	Pandalid shrimps	Carnivorous macrobenthos	5
			Pasiphaeidae	Glass shrimps	Carnivorous macrobenthos	4
			Pinnotheridae	Pea crabs	Carnivorous macrobenthos	24
			Processidae	Night shrimps	Carnivorous macrobenthos	6
			Sergestidae	Prawns	Carnivorous macrobenthos	4
			Sicyoniidae	Rock shrimps	Carnivorous macrobenthos	9
			Solenoceridae	Salmon shrimps	Carnivorous macrobenthos	3
			Strahlaxiidae	Slow prawns	Carnivorous macrobenthos	1
			Upogebiidae	Mud shrimps	Carnivorous macrobenthos	6
			Albuneidae	Mole crabs	Crabs and lobsters	5
			Atelecyclidae	Horse crabs	Crabs and lobsters	1
			Calappidae	Box crabs	Crabs and lobsters	5
			Cancridae	Edible crabs	Crabs and lobsters	2
			Coenobitidae	Hermit crabs	Crabs and lobsters	1
			Cryptocheridae	Gall crabs	Crabs and lobsters	1
			Cyclodorippidae	Porter crabs	Crabs and lobsters	3
			Dairidae	Crabs	Crabs and lobsters	1
			Daldorfiidae	Elbow crabs	Crabs and lobsters	1
			Diogenidae	Hermit crabs	Crabs and lobsters	13
			Dorippidae	Sumo crabs	Crabs and lobsters	3
			Dromiidae	Sponge crabs	Crabs and lobsters	4
			Epialtidae	Kelp crabs	Crabs and lobsters	4
			Galatheidae	Squat lobsters	Crabs and lobsters	6

Table A-2 continued. Taxonomic organization of invertebrate functional groups.

Phylum	Class	Order	Family	Name	Functional group	No. of species
Arthropoda (cont).	Malacostraca (cont.)	Decapoda (cont.)	Gecarcinidae	Land crabs	Crabs and lobsters	2
			Goneplacidae	Rectangular crabs	Crabs and lobsters	11
			Grapsidae	Grapsid shore crabs	Crabs and lobsters	11
			Hippidae	Sand crabs	Crabs and lobsters	2
			Inachidae	Spider crabs	Crabs and lobsters	8
			Inachoididae	Brachyuran crabs	Crabs and lobsters	6
			Leucosiidae	Purse crabs	Crabs and lobsters	13
			Lithodidae	Stone and king crabs	Crabs and lobsters	4
			Mithracidae	Spider crabs	Crabs and lobsters	11
			Ocypodidae	Fiddler and ghost crabs	Crabs and lobsters	9
			Paguridae	Right-handed hermit crabs	Crabs and lobsters	21
			Palicidae	Stilt crabs	Crabs and lobsters	4
			Palinuridae	Spiny lobsters	Crabs and lobsters	2
			Parthenopidae	Elbow crabs	Crabs and lobsters	7
			Pisidae	Spider crabs	Crabs and lobsters	6
			Raninidae	Frog crabs	Crabs and lobsters	5
			Scyllaridae	Slipper crabs	Crabs and lobsters	1
			Tychidae	Spider crabs	Crabs and lobsters	2
			Xanthidae	Mud crabs	Crabs and lobsters	42
			Palaemonidae	Anenome shrimps	Infaunal epifaunal meiobenthos	22
			Porcellanidae	Porcelain crabs	Infaunal epifaunal meiobenthos	32
			Stenopodidae	Coral shrimps	Infaunal epifaunal meiobenthos	2
			Penaeidae	Penaeid shrimps	Penaeid shrimp	5
				Blue shrimp (*Litopenaeus stylirostris*)	J./ad. blue shrimp	1
			Portunidae	Swimming crabs	Crabs and lobsters	8
				Warrior swimming crab (*Callinectes bellicosus*)	J./ad. blue crab	1
				Arched swimming crab (*C. arcuatus*)	J./ad. blue crab	1
	Maxillopoda	Acrothoracica		Burrowing barnacles	Sessile invertebrates	1
		Pedunculata		Stalked barnacles	Sessile invertebrates	2
		Sessilia		Sessile barnacles	Sessile invertebrates	20
		Subclass copepoda		Copepods	Small zooplankton	*
	Pycnogonida			Sea spiders	Carnivorous macrobenthos	13
Brachiopoda				Lampshells	Sessile invertebrates	2
Bryozoa				Moss animals	Sessile invertebrates	157
Chaetognatha				Arrow worms	Infaunal epifaunal meiobenthos	9
				Arrow worms	Large zooplankton	3
Chordata	Ascidiacea			Sea squirts	Sessile invertebrates	16
Cnidaria	Hydrozoa	Chondrophora		Hydrozoan	Jellyfish	3
		Filifera		Hydromedusas	Jellyfish	1
		Hydroida		Hydroids	Jellyfish	84

Table A-2 continued. Taxonomic organization of invertebrate functional groups.

Phylum	Class	Order	Family	Name	Functional group	No. of species
Cnidaria (cont.)	Hydrozoa	Siphonophora		Physalids	Jellyfish	14
	(cont.)	Capitata		Hydrocorals	Sessile invertebrates	1
	Anthozoa			Sea anemones, corals	Sessile invertebrates	78
	Scyphozoa			True jellyfish	Jellyfish	2
Ctenophora				Comb jellies	Large zooplankton	3
Echinodermata	Asteroidea			Sea stars	Carnivorous macrobenthos	43
	Ophiuroidea			Basket stars, brittlestars, snake stars	Carnivorous macrobenthos	56
	Echinoidea			Sea urchins, heart urchins, sand dollars	Herbivorous echinoderms	39
	Holothuroidea			Sea cucumbers	Sea cucumbers	42
Echiura				Spoon worms	Infaunal epifaunal meiobenthos	2
Hemichordata				Acorn worms	Infaunal epifaunal meiobenthos	*
Mollusca	Polyplacophora			Chitons	Carnivorous macrobenthos	50
	Gastropoda			Gastropods	Snails	1,111
	Pelecypoda			Bivalves	Bivalves	416
				Callo de escarlopa (*Spondylus calcifer*)	Scallops and penshells	1
				Callo de árbol (*Pteria sterna*)	Scallops and penshells	1
				Callo de hacha (*Pinna rugosa*)	Scallops and penshells	1
				Callo de riñón (*Atrina tuberculosa*)	Scallops and penshells	1
				Callo mechudo (*Spondylus princeps*)	Scallops and penshells	1
				Madreperla (*Pinctada mazatlanica*)	Scallops and penshells	1
	Cephalopoda	Octopoda		Octopus	Carnivorous macrobenthos	10
		Teuthoidea		Squids	Squid	4
	Scaphopoda			Tusk shells	Infaunal epifaunal meiobenthos	17
Nemertea				Ribbon worms	Infaunal epifaunal meiobenthos	10
Platyhelminthes				Flatworms	Infaunal epifaunal meiobenthos	21
Porifera				Sponges	Sessile invertebrates	65
Sipuncula				Peanut worms	Infaunal epifaunal meiobenthos	7
					Total	3,491

*Number of species not specified in Findley and Brusca (2005).

Table A-3. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
Gulf coney (FBP)			**0.458**	**0.458**	**0.152**	**105.3**	**14**	**92.8**	**0.015**	**3.041**	**5.7**	**22.5**
9205	Gulf coney (*Epinephelus acanthistius*)	Serranidae	—	—	—	105.3	—	92.8	0.015	3.041	5.7	22.5
Extranjero (FDB)			**1.379**	**1.379**	**0.835**	**53.2**	**15**	**50.7**	**0.009**	**3.090**	**5.9**	**35.0**
14239	Parrot sand bass (*Paralabrax loro*)	Serranidae	—	—	0.835	40.0	—	50.7	0.009	3.090	5.9	35.0
14238	Goldspotted sand bass (*P. auroguttatus*)	Serranidae	—	—	—	60.0	—	—	0.009	3.090	—	—
Leopard grouper (FDC)			**0.270**	**0.270**	**0.092**	**99.2**	**33**	**94.5**	**0.001**	**3.661**	**4.5**	**42.0**
9398	Leopard grouper (*Mycteroperca rosacea*)	Serranidae	—	—	0.092	86.4	—	94.5	0.001	3.661	4.5	42.0
Gulf grouper (FDD)			**0.458**	**0.458**	**0.152**	**153.3**	**20**	**146.0**	**0.019**	**3.000**	**2.7**	**30.0**
3333	Gulf grouper (*M. jordani*)	Serranidae	—	—	—	137.0	—	146.0	0.019	3.000	2.7	—
Amarillo snapper (FDE)			**0.406**	**0.406**	**0.155**	**68.6**	**21**	**66.0**	**0.026**	**2.963**	**2.3**	**36.0**
1408	Yellow snapper (*Lutjanus argentiventris*)	Lutjanidae	0.406	—	0.155	68.6	—	66.0	0.026	2.963	1.7	36.0
Barred pargo (FDF)			**0.458**	**0.458**	**0.152**	**96.6**	**20**	**92.0**	**0.007**	**3.245**	**4.3**	**21.5**
1393	Barred pargo (*Hoplopagrus guentherii*)	Lutjanidae	—	—	—	60.0	—	92.0	0.007	3.245	—	21.5
Groupers and snappers (FDM)			**0.458**	**0.229**	**0.152**	**54.8**	**24**	**48.3**	**0.019**	**2.955**	**10.0**	**30.0**
3312	Threadfin bass (*Pronotogrammus multifasciatus*)	Serranidae	—	—	—	27.4	—	9.1	0.032	2.550	—	—
3326	Splittail bass (*Hemanthias peruanus*)	Serranidae	—	—	—	47.4	—	—	—	—	—	—
8761	Panama graysby (*Cephalopholis panamensis*)	Serranidae	0.628	—	0.196	24.9	—	—	0.022	3.035	—	—
14232	Highfin sand perch (*Diplectrum labarum*)	Serranidae	—	—	—	22.0	—	—	0.014	2.970	—	—
14296	Bigeye bass (*Pronotogrammus eos*)	Serranidae	—	—	—	18.9	—	—	—	—	—	—
50095	Deepwater serrano (*Serranus aequidens*)	Serranidae	—	—	—		—	—	—	—	—	—
61270	Scalyfin basslet (*Liopropoma longilepis*)	Serranidae	—	—	—		—	—	—	—	—	—
8727	Pacific mutton hamlet (*Alphestes immaculatus*)	Serranidae	—	—	—	31.6	—	—	—	—	—	—
14231	Bighead sand perch (*Diplectrum euryplectrum*)	Serranidae	—	—	—	16.9	—	—	0.011	3.050	—	—
14244	Mexican sand perch (*D. macropoma*)	Serranidae	—	—	—	18.9	—	—	—	—	—	—
14248	Pacific sand perch (*D. pacificum*)	Serranidae	—	—	—	29.5	—	—	—	—	—	—
14250	Squirrel sand perch (*D. sciurus*)	Serranidae	—	—	—	17.9	—	—	—	—	—	—
8726	Mutton hamlet (*Alphestes afer*)	Serranidae	—	—	—	34.7	—	—	—	—	—	—
348	Spotted cabrilla (*Epinephelus analogus*)	Serranidae	—	—	—	104.0	—	—	0.020	3.000	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
9185	Leather bass (*Dermatolepis dermatolepis*)	Serranidae	—	—	—	90.2	—	—	0.017	3.000	—	—
16	Goliath grouper (*Epinephelus itajara*)	Serranidae	0.263	—	0.126	201.0	—	—	0.013	3.056	—	—
8196	Flag cabrilla (*E. labriformis*)	Serranidae	0.709	—	0.260	31.0	—	—	0.031	2.926	—	—
8728	Rivulated mutton hamlet (*Alphestes multiguttatus*)	Serranidae	—	—	—	26.3	—	—	—	—	—	—
9594	Star-studded grouper (*Epinephelus niphobles*)	Serranidae	—	—	—	50.5	—	—	—	—	—	—
1208	Snowy grouper (*E. niveatus*)	Serranidae	0.180		0.082	129.0	27	—	0.039	2.871	5.0	—
1405	Mullet snapper (*Lutjanus aratus*)	Lutjanidae	—	—	—	109.0	—	—	0.013	3.000	—	—
1426	Colorado snapper (*L. colorado*)	Lutjanidae	—	—	—	79.0	—	—	0.015	3.000	—	—
152	Spotted rose snapper (*L. guttatus*)	Lutjanidae	—	—	—	45.1	—	—	0.014	3.000	—	—
169	Pacific snapper (*L. novemfasciatus*)	Lutjanidae	—	—	—	135.0	—	—	0.015	3.000	—	—
170	Pacific red snapper (*L. peru*)	Lutjanidae	0.630	—	0.140	87.0	—	79.9	0.025	2.782	—	—
183	Blue-and-gold snapper (*L. viridis*)	Lutjanidae	—	—	—	31.6	—	—	—	—	—	—
9394	Sawtail grouper (*Mycteroperca prionura*)	Serranidae	—	—	—	105.0	—	—	0.012	3.000	—	—
3334	Broom-tail grouper (*M. xenarcha*)	Serranidae	—	—	—	127.0	—	—	0.018	3.000	—	—
3336	Spotted sand bass (*Paralabrax maculatofasciatus*)	Serranidae	0.340		0.110	33.0	20	56.0	0.020	3.000	15.0	—
8325	Pacific creolefish (*Paranthias colonus*)	Serranidae	—	—	—	37.5	—	—	—	—	—	—
46538	Pacific reef bass (*Pseudogramma thaumasium*)	Serranidae	—	—	—	8.8	—	—	—	—	—	—
25545	Mottled soapfish (*Rypticus bicolor*)	Serranidae	—	—	—	29.5	—	—	—	—	—	—
8331	Twice-spotted soapfish (*R. nigripinnis*)	Serranidae	—	—	—	21.4	—	—	—	—	—	—
12861	Blacktip grouper (*Serranus fasciatus*)	Serranidae	—	—	—	18.7	—	—	—	—	—	—
14298	Barred serrano (*S. psittacinus*)	Serranidae	—	—	—	18.9	—	—	—	—	—	—
Drums and croakers (FDO)			**0.865**	**0.433**	**0.501**	**44.2**	**13**	**41.9**	**0.010**	**3.006**	**2.1**	**35.0**
3578	White seabass (*Atractoscion nobilis*)	Sciaenidae	0.300	—	0.128	146.0	20	152.0	0.012	2.942	3.0	35.0
3579	Bairdiella (*Bairdiella icistia*)	Sciaenidae	—	—	—	31.6	—	—	—	—	—	—
3580	Black croaker (*Cheilotrema saturnum*)	Sciaenidae	0.503	—	0.183	47.0	—	—	—	—	2.1	—
3581	Shortfin corvina (*Cynoscion parvipinnis*)	Sciaenidae	—	—	—	68.6	—	—	0.010	3.000	—	—
3590	Yellowfin croaker (*Umbrina roncador*)	Sciaenidae	—	—	—	55.9	10	55.6	0.014	3.000	1.7	—
13990	Dusky croaker (*Ophioscion scierus*)	Sciaenidae	—	—	—	36.8	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
13993	Yelloweye croaker (*Odontoscion xanthops*)	Sciaenidae	—	—	—	31.6	—	—	—	—	—	—
13996	Gulf croaker (*Micropogonias megalops*)	Sciaenidae	—	—	—	42.1	—	42.0	—	2.939	2.3	—
13997	Slender croaker (*M. ectenes*)	Sciaenidae	—	—	—	42.1	—	—	—	—	—	—
13998	Golden croaker (*M. altipinnis*)	Sciaenidae	—	—	—	69.5	—	—	—	—	—	—
14003	Highfin kingfish (*Menticirrhus nasus*)	Sciaenidae	—	—	—	52.6	—	—	—	—	—	—
14011	Shining drum (*Larimus effulgens*)	Sciaenidae	—	—	—	29.5	—	—	—	—	—	—
14014	Silver drum (*L. argenteus*)	Sciaenidae	—	—	—	36.8	—	—	—	—	—	—
14015	Steeplined drum (*L. acclivis*)	Sciaenidae	—	—	—	27.4	—	—	—	—	—	—
14018	Bigeye corvina (*Isopisthus remifer*)	Sciaenidae	—	—	—	36.8	—	—	—	—	—	—
14023	Bluestreak drum (*Elattarchus archidium*)	Sciaenidae	—	—	—	26.3	—	—	—	—	—	—
14026	Gulf corvina (*Cynoscion othonopterus*)	Sciaenidae	—	—	—	63.5	—	—	0.015	2.892	—	—
14027	Dwarf corvina (*C. nannus*)	Sciaenidae	—	—	—	18.0	—	—	0.013	2.920	—	—
14066	Squint-eyed croaker (*Ophioscion strabo*)	Sciaenidae	—	—	—	31.6	—	—	—	—	—	—
14084	Silver stardrum (*Stellifer illecebrosus*)	Sciaenidae	—	—	—	26.3	—	—	—	—	—	—
14097	Cortez drum (*Umbrina wintersteeni*)	Sciaenidae	—	—	—	31.6	—	—	—	—	—	—
14098	Surf croaker (*U. xanti*)	Sciaenidae	—	—	—	36.8	—	—	—	—	—	—
14101	Vacuocua croaker (*Corvula macrops*)	Sciaenidae	—	—	—	21.4	—	—	0.010	3.160	—	—
14110	Scalyfin corvina (*Cynoscion squamipinnis*)	Sciaenidae	—	—	—	67.4	—	—	—	—	—	—
14623	Armed croaker (*Bairdiella armata*)	Sciaenidae	—	—	—	31.6	—	—	—	—	—	—
14030	Striped corvina (*Cynoscion reticulates*)	Sciaenidae	—	—	—	50.8	—	—	0.009	3.000	—	—
3582	Orangemouth corvina (*C. xanthulus*)	Sciaenidae	1.830	—	1.308	44.8	—	—	0.004	3.204	—	—
14009	Pacific drum (*Larimus pacificus*)	Sciaenidae	—	—	—	31.6	—	—	—	—	—	—
3587	California corbina (*Menticirrhus undulates*)	Sciaenidae	0.828	—	0.385	44.4	8	83.6	0.010	3.000	1.5	—
Grunts (FDP)			**0.411**	**0.205**	**0.126**	**37.7**	**14**	**16.5**	**0.056**	**2.824**	**2.0**	**30.0**
8253	Burrito grunt (*Anisotremus interruptus*)	Haemulidae	0.400	—	0.130	48.2	—	—	0.057	2.910	—	—
13706	Armed grunt (*Conodon serrifer*)	Haemulidae	—	—	—	31.6	—	—	—	—	—	—
13701	Silvergray grunt (*Anisotremus caesius*)	Haemulidae	—	—	—	31.6	—	—	—	—	—	—
3568	Sargo (*A. davidsonii*)	Haemulidae	—	—	—	61.1	—	—	—	—	—	—
8248	Blackbarred grunt (*A. dovii*)	Haemulidae	—	—	—	47.4	—	—	—	—	—	—
13703	Pacific porkfish (*A. taeniatus*)	Haemulidae	—	—	—	31.6	—	9.7	0.020	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
13707	Cortez grunt (*Haemulon flaviguttatum*)	Haemulidae	0.383	—	0.115	42.4	—	—	0.103	2.600	—	—
8317	Spottail grunt (*H. maculicauda*)	Haemulidae	0.430	—	0.120	30.9	—	4.6	0.056	2.862	—	—
13717	Mojarra grunt (*H. scudderii*)	Haemulidae	—	—	—	36.8	—	—	—	—	—	—
13718	Graybar grunt (*H. sexfasciatum*)	Haemulidae	—	—	0.132	49.0	—	—	0.081	2.710	—	—
1142	Latin grunt (*H. steindachneri*)	Haemulidae	—	—	—	22.5	—	4.9	0.039	2.910	—	—
3569	Wavyline grunt (*Microlepidotus inornatus*)	Haemulidae	—	—	—	20.9	14	58.0	0.015	2.930	2.0	—
13723	Humpback grunt (*Orthopristis chalceus*)	Haemulidae	—	—	—	47.4	—	4.0	0.016	—	—	—
13724	Bronzestriped grunt (*O. reddingi*)	Haemulidae	0.440	—	0.134	36.8	—	—	0.150	2.450	—	—
13740	Panamic grunt (*Pomadasys panamensis*)	Haemulidae	—	—	—	33.7	—	6.3	0.020	3.220	—	—
3570	Salema (*Xenistius californiensis*)	Haemulidae	—	—	—	31.6	—	27.9	—	—	—	—
Herbivorous fish (FDS)			**1.302**	**0.651**	**0.718**	**44.2**	**16**	**42.0**	**0.026**	**2.945**	**3.4**	**38.3**
1261	Yellowfin surgeonfish (*Acanthurus xanthopterus*)	Acanthuridae	—	—	—	57.0	—	—	0.047	2.787	—	—
13419	Yellowtail surgeonfish (*Prionurus punctatus*)	Acanthuridae	—	—	—	63.2	—	—	—	—	—	—
4306	Achilles tang (*Acanthurus Achilles*)	Acanthuridae	—	—	—	22.6	—	—	0.003	3.000	—	—
6011	Goldrim surgeonfish (*A. nigricans*)	Acanthuridae	—	—	—	22.4	—	—	0.067	2.669	—	59.0
4357	Spinytooth parrotfish (*Calotomus spinidens*)	Scaridae	1.839	—	0.975	22.2	—	—	0.012	3.212	—	—
3594	Opaleye (*Girella nigricans*)	Kyphosidae	—	—	—	69.5	—	—	—	—	—	—
3595	Zebraperch (*Hermosilla azurea*)	Kyphosidae	—	—	—	47.4	—	44.0	—	—	—	—
785	Striped mullet (*Mugil cephalus*)	Mugilidae	0.466	—	0.306	60.4	16	211.0	0.019	2.978	4.3	42.0
1086	White mullet (*M. curema*)	Mugilidae	1.827	—	1.204	37.1	—	33.8	0.022	2.823	2.5	14.0
13980	Loosetooth parrotfish (*Nicholsina denticulata*)	Scaridae	—	—	—	24.2	—	—	—	—	—	—
13981	Azure parrotfish (*Scarus compressus*)	Scaridae	—	—	—	56.8	—	—	—	—	—	—
5548	Bluechin parrotfish (*S. ghobban*)	Scaridae	1.147	—	0.517	27.5	13		0.020	2.984	—	—
8392	Bumphead parrotfish (*S. perrico*)	Scaridae	—	—	—	80.0	—	—	—	—	—	—
5555	Bicolor parrotfish (*S. rubroviolaceus*)	Scaridae	1.230	—	0.589	29.0	20	—	0.014	3.109	—	—
Large reef fish (FMM)			**0.481**	**0.240**	**0.259**	**75.8**	**56**	**72.0**	**0.018**	**2.999**	**6.3**	**44.5**
1260	Convict surgeon (*Acanthurus triostegus*)	Acanthuridae	1.473	—	0.675	20.9	—	—	0.044	2.935	—	45.0
4276	Finescale triggerfish (*Balistes polylepis*)	Balistidae	—	—	—	80.0	—	55.8	—	2.700	—	—
8226	Blunthead triggerfish (*Pseudobalistes naufragium*)	Balistidae	—	—	—	105.3	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5. NCN = no common name.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
13533	Orangeside triggerfish (*Sufflamen verres*)	Balistidae	—	—	—	42.1	—	—	—	—	—	—
60609	NCN (*Chlopsis kazuko*)	Chlopsidae	—	—	—	11.9	—	—	—	—	—	—
13596	Peppered garden eel (*Gorgasia punctata*)	Congridae	—	—	—	52.6	—	—	—	—	—	—
13600	Cape garden eel (*Heteroconger canabus*)	Congridae	—	—	—	84.2	—	—	—	—	—	—
13601	Cortez garden eel (*H. digueti*)	Congridae	—	—	—	66.3	—	—	—	—	—	—
13603	Sharpnose conger (*Ariosoma gilberti*)	Congridae	—	—	—	28.4	—	—	—	—	—	—
13608	Shorttail conger (*Paraconger similis*)	Congridae	—	—	—	31.6	—	—	—	—	—	—
13613	Ringeye conger (*P. californiensis*)	Congridae	—	—	—	63.2	—	—	—	—	—	—
13615	Shorthead conger (*Bathycongrus macrurus*)	Congridae	—	—	—	26.3	—	—	—	—	—	—
13616	Largehead conger (*B. varidens*)	Congridae	—	—	—	105.3	—	—	—	—	—	—
13622	Hardtail conger (*Gnathophis cinctus*)	Congridae	—	—	—	44.2	—	—	—	—	—	—
13624	Needletail conger (*Rhynchoconger nitens*)	Congridae	—	—	—	42.1	—	—	—	—	—	—
13860	Cortez rainbow wrasse (*Thalassoma lucasanum*)	Labridae	—	—	—	15.8	—	—	—	—	—	76.8
59502	NCN (*Nemichthys larseni*)	Nemichthyidae	—	—	—	169.2	—	—	—	—	—	—
2650	Tiger snake eel (*Myrichthys maculosus*)	Ophichthidae	—	—	—	105.3	—	—	—	—	—	—
2653	Pacific worm eel (*Myrophis vafer*)	Ophichthidae	—	—	—	48.4	—	—	—	—	—	—
2657	Pacific snake eel (*Ophichthus triserialis*)	Ophichthidae	—	—	—	118.9	—	—	—	—	—	—
2658	Yellow snake eel (*O. zophochir*)	Ophichthidae	0.400	—	0.300	76.0	—	—	0.001	3.000	—	—
13902	Sandy ridgefin eel (*Callechelys cliffi*)	Ophichthidae	—	—	—	47.9	—	—	—	—	—	—
13903	Spotted ridgefin eel (*C. eristigma*)	Ophichthidae	—	—	—	118.9	—	—	—	—	—	—
13906	Ordinary eel (*Ethadophis byrnei*)	Ophichthidae	—	—	—	53.7	—	—	—	—	—	—
61190	NCN (*Apterichtus gymnocelus*)	Ophichthidae	—	—	—	—	—	—	—	—	—	—
8275	Pacific bearded brotula (*Brotula clarkae*)	Ophidiidae	—	—	—	—	—	—	—	—	—	—
13930	Finescale cusk-eel (*Lepophidium microlepis*)	Ophidiidae	—	—	—	26.1	—	—	—	—	—	—
13931	Specklefin cusk-eel (*L. negropinna*)	Ophidiidae	—	—	—	50.0	—	—	—	—	—	—
13932	Leopard cusk-eel (*L. pardale*)	Ophidiidae	—	—	—	20.3	—	—	—	—	—	—
13933	Prowspine cusk-eel (*L. prorates*)	Ophidiidae	—	—	—	28.5	—	—	—	—	—	—
13934	Mexican cusk-eel (*L. stigmatistium*)	Ophidiidae	—	—	—	24.8	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
47393	Velvetnose brotula (*Petrotyx hopkinsi*)	Ophidiidae	—	—	—	21.1	—	—	—	—	—	—
54200	Thread brotula (*Neobythites stelliferoides*)	Ophidiidae	—	—	—	—	—	—	—	—	—	—
3267	Oarfish (*Regalecus glesne*)	Regalecidae	—	—	—	1,157.9	—	—	—	—	—	—
3964	Splitnose rockfish (*Sebastes diploproa*)	Sebastidae	—	—	0.130	41.3	84	46.0	0.012	3.000	—	—
3977	Mexican rockfish (*S. macdonaldi*)	Sebastidae	—	—	—	55.9	—	—	0.015	3.000	—	—
14197	Blackmouth rockfish (*S. sinensis*)	Sebastidae	—	—	—	16.0	—	—	—	—	—	—
14228	Cortez rockfish (*S. cortezi*)	Sebastidae	—	—	—	26.8	—	—	—	—	—	—
14229	Buccaneer rockfish (*S. exsul*)	Sebastidae	—	—	—	22.3	—	—	—	—	—	—
1288	Atlantic cutlassfish (*Trichiurus lepturus*)	Trichiuridae	0.290	—	0.322	79.4	15	—	0.009	3.278	1.8	—
8270	Mexican hogfish (*Bodianus diplotaenia*)	Labridae	—	—	—	80.0	—	—	—	—	—	39.8
13835	Blackspot wrasse (*Decodon melasma*)	Labridae	—	—	—	24.2	—	—	—	—	—	—
13838	Mangrove wrasse (*Halichoeres aestuaricola*)	Labridae	—	—	—	23.2	—	—	—	—	—	—
13839	Wounded wrasse (*H. chierchiae*)	Labridae	—	—	—	18.4	—	—	—	—	—	31.4
8208	Chameleon wrasse (*H. dispilus*)	Labridae	—	—	—	26.3	—	—	—	—	—	41.4
13846	Spinster wrasse (*H. nicholsi*)	Labridae	—	—	—	40.0	—	—	—	—	—	32.1
8330	Banded wrasse (*H. notospilus*)	Labridae	—	—	—	26.7	—	—	—	—	—	38.2
3667	Rock wrasse (*H. semicinctus*)	Labridae	—	—	—	40.0	—	—	—	—	—	30.0
60984	Pacific tripletail (*Lobotes pacificus*)	Lobotidae	—	—	—	105.3	—	—	—	—	—	—
3550	Roosterfish (*Nematistius pectoralis*)	Nematistiidae	—	—	—	162.0	—	—	0.012	3.000	—	—
14073	Festive drum (*Pareques fuscovittatus*)	Sciaenidae	—	—	—	21.1	—	—	—	—	—	—
8327	Rock croaker (*P. viola*)	Sciaenidae	—	—	—	26.3	—	—	—	—	—	—
59642	Cape wrasse (*Pseudojuloides inornatus*)	Labridae	—	—	—	—	—	—	—	—	—	—
13845	Golden wrasse (*Halichoeres melanotis*)	Labridae	—	—	—	13.7	—	—	—	—	—	35.6
3671	California sheephead (*Semicossyphus pulcher*)	Labridae	0.170	—	0.090	76.2	53	91.0	0.029	3.000	5.0	41.1
3310	Giant sea bass (*Stereolepis gigas*)	Polyprionidae	0.070	—	0.040	226.0	70	228.6	0.022	3.000	12.0	—
5646	Yellow-brown wrasse (*Thalassoma lutescens*)	Labridae	—	—	—	16.5	—	—	0.012	3.077	—	78.0
5647	Surge wrasse (*T. purpureum*)	Labridae	—	—	—	36.0	—	—	0.026	3.000	—	—
Small reef fish (FMN)			**0.836**	**0.209**	**0.390**	**31.7**	**10**	**30.1**	**0.053**	**2.964**	**3.3**	**48.8**
13451	Sanguine frogfish (*Antennarius sanguineus*)	Antennariidae	—	—	—	8.6	—	—	—	—	—	—
46598	Barspot cardinalfish (*Apogon retrosella*)	Apogonidae	—	—	—	10.5	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
972	Flat needlefish (*Ablennes hians*)	Belonidae	0.836		0.605	123.0	—	—	0.001	3.226	—	—
8269	Barnaclebill blenny (*Hypsoblennius brevipinnis*)	Blenniidae	—	—	—	12.6	—	—	—	—	—	—
46791	Notchfin blenny (*Entomacrodus chiostictus*)	Blenniidae	—	—	—	7.9	—	—	—	—	—	—
3125	Purple brotula (*Grammonus diagrammus*)	Bythitidae	—	—	—	21.4	—	—	—	—	—	—
46703	Clubhead barnacle blenny (*Acanthemblemaria balanorum*)	Chaenopsidae	—	—	—	4.7	—	—	—	—	—	—
46704	Browncheek blenny (*A. crockery*)	Chaenopsidae	—	—	—	6.3	—	—	—	—	—	—
46728	Angel blenny (*Coralliozetus angelicus*)	Chaenopsidae	—	—	—	3.7	—	—	—	—	—	—
46729	Zebraface blenny (*C. micropes*)	Chaenopsidae	—	—	—	4.2	—	—	—	—	—	—
46785	Plume blenny (*Cirriemblemaria lucasana*)	Chaenopsidae	—	—	—	4.2	—	—	—	—	—	—
47396	Warthead blenny (*Protemblemaria bicirrus*)	Chaenopsidae	—	—	—	4.7	—	—	—	—	—	—
3603	Scythe butterflyfish (*Prognathodes falcifer*)	Chaetodontidae	—	—	—	15.8	—	—	—	—	—	—
5584	Forcepsfish (*Forcipiger flavissimus*)	Chaetodontidae	—	—	—	14.4	—	—	0.017	3.000	—	49.0
8278	Threebanded butterflyfish (*Chaetodon humeralis*)	Chaetodontidae	—	—	—	26.7	—	—	—	—	—	—
12310	Barberfish (*Johnrandallia nigrirostris*)	Chaetodontidae	—	—	—	21.1	—	—	—	—	—	—
5830	Coral hawkfish (*Cirrhitichthys oxycephalus*)	Cirrhitidae	—	—	—	10.5	—	—	0.033	3.000	—	—
5833	Longnose hawkfish (*Oxycirrhites typus*)	Cirrhitidae	—	—	—	13.7	—	—	—	—	—	67.5
6408	Giant hawkfish (*Cirrhitus rivulatus*)	Cirrhitidae	—	—	—	53.0	—	—	0.028	3.000	—	—
1022	Porcupinefish (*Diodon hystrix*)	Diodontidae	—	—	—	54.5	—	—	0.409	2.311	—	—
4659	Balloonfish (*D. holocanthus*)	Diodontidae	—	—	—	29.5	—	—	0.150	2.707	—	—
3599	Pacific spadefish (*Chaetodipterus zonatus*)	Ephippidae	—	—	—	68.4	—	—	—	—	—	—
5444	Reef cornetfish (*Fistularia commersonii*)	Fistulariidae	—	—	—	96.8	—	—	0.001	3.000	—	—
46470	Rockwall clingfish (*Arcos erythrops*)	Gobiesocidae	—	—	—	3.7	—	—	—	—	—	—
46473	Panamic clingfish (*Gobiesox adustus*)	Gobiesocidae	—	—	—	4.7	—	—	—	—	—	—
46922	Sonora clingfish (*Tomicodon humeralis*)	Gobiesocidae	—	—	—	8.9	—	—	—	—	—	—
55739	Zebra clingfish (*T. zebra*)	Gobiesocidae	—	—	—	6.3	—	—	—	—	—	—
8293	Paradox goby (*Gobiosoma paradoxum*)	Gobiidae	—	—	—	—	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
12230	Cortez sea chub (*Kyphosus elegans*)	Kyphosidae	—	—	—	40.0	—	—	—	—	—	—
8322	Topgallant blenny (*Paraclinus altivelis*)	Labrisomidae	—	—	—	—	—	—	—	—	—	—
46702	Redrump blenny (*Xenomedea rhodopyga*)	Labrisomidae	—	—	—	6.8	—	—	—	—	—	—
7870	Largehead moray (*Uropterygius macrocephalus*)	Muraenidae	—	—	—	42.1	—	—	—	—	—	—
7880	Zebra moray (*Gymnomuraena zebra*)	Muraenidae	—	—	—	157.9	—	—	—	—	—	—
8207	Jewel moray (*Muraena lentiginosa*)	Muraenidae	—	—	—	64.2	—	—	—	—	—	—
8287	Palenose moray (*Echidna nocturna*)	Muraenidae	—	—	—	74.7	—	—	—	—	—	—
13780	Slenderjaw moray (*Enchelycore octaviana*)	Muraenidae	—	—	—	95.8	—	—	—	—	—	—
13782	Panamic green moray (*Gymnothorax castaneus*)	Muraenidae	—	—	—	157.9	—	—	—	—	—	—
13783	Finespotted moray (*G. dovii*)	Muraenidae	—	—	—	178.9	—	—	—	—	—	—
13786	Masked moray (*G. panamensis*)	Muraenidae	—	—	—	73.7	—	—	—	—	—	—
13789	Argus moray (*Muraena argus*)	Muraenidae	—	—	—	105.3	—	—	—	—	—	—
13790	Hourglass moray (*M. clepsydra*)	Muraenidae	—	—	—	102.1	—	—	—	—	—	—
8294	King angelfish (*Holacanthus passer*)	Pomacanthidae	—	—	—	37.5	—	—	—	—	—	—
8328	Cortez angelfish (*Pomacanthus zonipectus*)	Pomacanthidae	—	—	—	48.4	—	30.4	0.006	—	—	—
8245	Panamic sergeant major (*Abudefduf troschelii*)	Pomacentridae	—	—	—	18.9	—	—	—	—	—	22.5
8279	Scissortail chromis (*Chromis atrilobata*)	Pomacentridae	—	—	—	13.7	—	—	—	—	—	30.0
11793	Dusky sergeant (*Abudefduf concolor*)	Pomacentridae	—	—	—	20.0	—	—	—	—	—	—
11853	Silverstripe chromis (*Chromis alta*)	Pomacentridae	—	—	—	13.7	—	—	—	—	—	—
11869	Blue-and-yellow chromis (*C. limbaughi*)	Pomacentridae	—	—	—	10.5	—	—	—	—	—	—
12453	Bumphead damselfish (*Microspathodon bairdii*)	Pomacentridae	—	—	—	26.3	—	—	—	—	—	—
12455	Giant damselfish (*M. dorsalis*)	Pomacentridae	—	—	—	32.6	—	—	—	—	—	—
12514	Whitetail damselfish (*Stegastes leucorus*)	Pomacentridae	—	—	—	14.7	—	—	—	—	—	—
12516	Cortez damselfish (*S. rectifraenum*)	Pomacentridae	—	—	—	9.5	—	—	—	—	—	—
55868	Mexican night sergeant (*Abudefduf declivifrons*)	Pomacentridae	—	—	—	18.9	—	—	—	—	—	—
2721	California lizardfish (*Synodus lucioceps*)	Synodontidae	—	—	—	67.4	—	—	—	—	—	—
4293	Bullseye puffer (*Sphoeroides annulatus*)	Tetraodontidae	—	—	—	33.0	—	31.8	0.018	3.050	2.6	—
6401	Guineafowl puffer (*Arothron meleagris*)	Tetraodontidae	—	—	—	52.6	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
14159	Spotted sharpnosed puffer (*Canthigaster punctatissima*)	Tetraodontidae	—	—	—	9.5	—	—	—	—	—	—
46539	Carmine triplefin (*Enneanectes carminalis*)	Tripterygiidae	—	—	—	3.2	—	—	—	—	—	—
5950	Moorish idol (*Zanclus cornutus*)	Zanclidae	—	—	—	24.2	—	—	0.017	3.171	—	—
46717	Mexican blenny (*Acanthemblemaria macrospilus*)	Chaenopsidae	—	—	—	6.3	—	—	—	—	—	—
4275	Scrawled filefish (*Aluterus scriptus*)	Monacanthidae	—	—	—	62.0	—	—	0.002	3.000	—	—
46600	Plain cardinalfish (*Apogon atricaudus*)	Apogonidae	—	—	—	8.4	—	—	—	—	—	—
8256	Tailspot cardinalfish (*A. dovii*)	Apogonidae	—	—	—	7.9	—	—	—	—	—	—
25508	Pink cardinalfish (*A. pacificus*)	Apogonidae	—	—	—	10.5	—	—	—	—	—	—
5425	Stripebelly puffer (*Arothron hispidus*)	Tetraodontidae	—	—	—	46.0	—	—	0.057	2.801	—	—
8259	Panamic frillfin (*Bathygobius ramosus*)	Gobiidae	—	—	—	12.0	—	—	—	—	—	—
3293	Snubnose pipefish (*Cosmocampus arctus arctus*)	Syngnathidae	—	—	—	12.6	—	—	—	—	—	—
5836	Barred filefish (*Cantherhines dumerilii*)	Monacanthidae	—	—	—	40.0	—	—	0.041	2.792	—	—
3539	Ocean whitefish (*Caulolatilus princeps*)	Malacanthidae	—	—	0.175	62.2	13	102.0	0.024	3.000	4.0	90.0
4298	Pacific burrfish (*Chilomycterus affinis*)	Diodontidae	—	—	—	57.9	—	—	—	—	—	—
46733	Spikefin blenny (*Coralliozetus rosenblatti*)	Chaenopsidae	—	—	—	3.7	—	—	—	—	—	—
5969	Fantail pipefish (*Doryrhamphus excisus excisus*)	Syngnathidae	—	—	—	7.4	—	—	—	—	—	—
46896	Banded cleaning goby (*Elacatinus digueti*)	Gobiidae	—	—	—	3.4	—	—	—	—	—	—
46894	Redhead goby (*E. puncticulatus*)	Gobiidae	—	—	—	4.6	—	—	—	—	—	—
12512	Beaubrummel (*Stegastes flavilatus*)	Pomacentridae	—	—	—	10.5	—	—	—	—	—	28.5
12517	Clarion damselfish (*S. redemptus*)	Pomacentridae	—	—	—	12.6	—	—	—	—	—	—
46866	Sonora goby (*Gobiosoma chiquita*)	Gobiidae	—	—	—	6.8	—	—	—	—	—	—
46907	Knobchin goby (*G. nudum*)	Gobiidae	—	—	—	4.7	—	—	—	—	—	—
46878	Sandtop goby (*Gobulus hancocki*)	Gobiidae	—	—	—	2.6	—	—	—	—	—	—
46892	Splitbanded goby (*Gymneleotris seminudus*)	Gobiidae	—	—	—	5.3	—	—	—	—	—	—
3284	Pacific seahorse (*Hippocampus ingens*)	Syngnathidae	—	—	—	31.6	—	—	—	—	—	—
11172	Clarion angelfish (*Holacanthus clarionensis*)	Pomacanthidae	—	—	—	21.1	—	—	—	—	—	—
3648	Garibaldi (*Hypsypops rubicundus*)	Pomacentridae	—	—	—	31.6	14	36.0	0.110	3.077	4.7	—
5790	Barred flagtail (*Kuhlia mugil*)	Kuhliidae	—	—	—	16.2	—	—	0.014	3.000	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
8295	Porehead blenny (*Labrisomus multiporosus*)	Labrisomidae	—	—	—	—	—	—	—	—	—	—
8297	Largemouth blenny (*L. xanti*)	Labrisomidae	—	—	—	18.7	—	—	—	—	—	—
6554	Spiny boxfish (*Lactoria diaphana*)	Ostraciidae	—	—	—	35.8	—	—	—	—	—	—
46859	Gorgeous goby (*Lythrypnus pulchellus*)	Gobiidae	—	—	—	4.7	—	—	—	—	—	—
46670	Sonora blenny (*Malacoctenus gigas*)	Labrisomidae	—	—	—	13.7	—	—	—	—	—	—
3597	Halfmoon (*Medialuna californiensis*)	Kyphosidae	—	—	—	50.5	—	48.0	0.000	3.260	2.0	—
46683	Foureye rockskipper (*Mnierpes macrocephalus*)	Labrisomidae	—	—	—	11.6	—	—	—	—	—	—
3591	Mexican goatfish (*Mulloidichthys dentatus*)	Mullidae	—	—	—	32.6	—	—	—	—	—	—
13752	Panamic soldierfish (*Myripristis leiognathus*)	Holocentridae	—	—	—	18.8	—	—	—	—	—	—
46467	Gulf brotula (*Ogilbia ventralis*)	Bythitidae	—	—	—	7.4	—	—	—	—	—	—
8300	Panamic fanged blenny (*Ophioblennius steindachneri*)	Blenniidae	—	—	—	18.9	—	—	—	—	—	—
46553	Bullseye jawfish (*Opistognathus scops*)	Opistognathidae	—	—	—	12.6	—	—	—	—	—	—
8324	Mexican blenny (*Paraclinus mexicanus*)	Labrisomidae	—	—	—	4.2	—	—	—	—	—	—
8326	Panama spadefish (*Parapsettus panamensis*)	Ephippidae	—	—	—	31.6	—	—	—	—	—	—
25513	Sabertooth blenny (*Plagiotremus azaleus*)	Blenniidae	—	—	—	10.5	—	—	—	—	—	—
1150	Glasseye snapper (*Heteropriacanthus cruentatus*)	Priacanthidae	—	—	—	34.0	—	—	0.019	3.000	—	—
3519	Popeye catalufa (*Pristigenys serrula*)	Priacanthidae	—	—	—	34.7	—	—	—	—	—	—
46846	Secret goby (*Pycnomma semisquamatum*)	Gobiidae	—	—	—	6.6	—	—	—	—	—	—
13791	Peppered moray (*Uropterygius polystictus*)	Muraenidae	—	—	—	75.8	—	—	—	—	—	—
7450	Tiger reef eel (*Scuticaria tigrina*)	Muraenidae	—	—	—	126.3	—	—	—	—	—	—
25522	Throatspotted blenny (*Malacoctenus tetranemus*)	Labrisomidae	—	—	—	7.9	—	—	—	—	—	—
6556	Spotted boxfish (*Ostracion meleagris*)	Ostraciidae	—	—	—	26.3	—	—	—	—	—	54.0
Small demersal fish (FPL)			**0.429**	**0.150**	**0.225**	**29.5**	**13**	**28.0**	**0.017**	**2.892**	**3.0**	**26.4**
228	Bonefish (*Albula vulpes*)	Albulidae	0.553	—	0.261	75.9	—	—	0.026	2.895	3.9	—
5200	Sharpchin slickhead (*Bajacalifornia burragei*)	Alepocephalidae	—	—	—	19.1	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5. NCN = no common name.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
12015	Panamic flashlightfish (*Phthanophaneron harveyi*)	Anomalopidae	—	—	—	8.4	—	—	—	—	—	—
3083	Roughjaw frogfish (*Antennarius avalonis*)	Antennariidae	—	—	—	34.7	—	—	—	—	—	—
13455	Bandtail frogfish (*Antennatus strigatus*)	Antennariidae	—	—	—	8.4	—	—	—	—	—	—
13478	Flathead sea catfish (*Notarius planiceps*)	Ariidae	—	—	—	62.1	—	—	—	—	—	—
13479	Cominate sea catfish (*Hexanematichthys platypogon*)	Ariidae	—	—	—	47.4	—	—	—	—	—	—
13481	Long-barbeled sea catfish (*Bagre pinnimaculatus*)	Ariidae	—	—	—	52.6	—	—	—	—	—	—
13507	Chili sea catfish (*Notarius troschelii*)	Ariidae	0.529	—	0.200	48.0	—	—	—	—	—	—
13526	Eastern Pacific flagfin (*Aulopus bajacali*)	Aulopidae	—	—	—	22.5	—	—	—	—	—	—
13547	Darkedge midshipman (*Porichthys analis*)	Batrachoididae	0.340	—	0.170	29.1	17	38.0	0.010	3.040	4.1	35.0
13548	Saddle midshipman (*P. ephippiatus*)	Batrachoididae	—	—	—	12.4	7	38.0	0.027	0.605	3.5	31.5
13551	Mimetic midshipman (*P. mimeticus*)	Batrachoididae	—	—	—	19.5	7	38.0	0.009	3.040	3.5	31.5
3162	California needlefish (*Strongylura exilis*)	Belonidae	—	—	—	95.8	—	—	—	—	—	—
13565	Keeltail needlefish (*Platybelone argalus pterura*)	Belonidae	—	—	—	42.1	—	—	—	—	—	—
13568	Pacific agujon (*Tylosurus pacificus*)	Belonidae	—	—	—	86.8	—	—	—	—	—	—
13570	Houndfish (*T. crocodilus fodiator*)	Belonidae	—	—	—	134.0	—	—	0.003	3.000	—	—
3761	Bay blenny (*Hypsoblennius gentilis*)	Blenniidae	—	—	—	15.8	—	—	—	—	—	—
3765	Mussel blenny (*H. jenkinsi*)	Blenniidae	—	—	—	13.7	—	—	—	—	—	—
61233	NCN (*H. digueti*)	Blenniidae	—	—	—	—	—	—	—	—	—	—
54789	East Pacific codlet (*Bregmaceros bathymaster*)	Bregmacerotidae	—	—	—	10.5	—	—	—	—	—	—
56420	Rubynose brotula (*Cataetyx rubrirostris*)	Bythitidae	—	—	—	16.5	—	—	—	—	—	—
46087	Pacific pearlfish (*Carapus dubius*)	Carapidae	—	—	—	15.8	—	—	—	—	—	—
52421	Nocturnal pearlfish (*Echiodon exsilium*)	Carapidae	—	—	—	13.3	—	—	—	—	—	—
6428	Black snook (*Centropomus nigrescens*)	Centropomidae	—	—	—	123.0	—	—	0.014	3.000	—	—
6429	Blackfin snook (*C. medius*)	Centropomidae	—	—	—	53.0	—	—	0.009	3.000	—	—
6430	White snook (*C. viridis*)	Centropomidae	—	—	—	96.0	—	—	0.013	3.000	—	—
10978	Yellowfin snook (*C. robalito*)	Centropomidae	—	—	—	36.3	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
46744	Reef-sand blenny (*Ekemblemaria myersi*)	Chaenopsidae	—	—	—	7.4	—	—	—	—	—	—
46774	Gulf signal blenny (*Emblemaria hypacanthus*)	Chaenopsidae	—	—	—	5.3	—	—	—	—	—	—
46780	Elusive signal blenny (*E. walkeri*)	Chaenopsidae	—	—	—	6.8	—	—	—	—	—	—
46788	Gulf worm blenny (*Stathmonotus sinuscalifornici*)	Chaenopsidae	—	—	—	6.8	—	—	—	—	—	—
54347	Cortez pikeblenny (*Chaenopsis coheni*)	Chaenopsidae	—	—	—	—	—	—	—	—	—	—
54348	Barcheek blenny (*Coralliozetus boehlkei*)	Chaenopsidae	—	—	—	—	—	—	—	—	—	—
46622	Whitesaddle stargazer (*Dactyloscopus pectoralis*)	Dactyloscopidae	—	—	—	5.5	—	—	—	—	—	—
46649	Halfbanded stargazer (*Gillellus semicinctus*)	Dactyloscopidae	—	—	—	5.5	—	—	—	—	—	—
51434	Giant stargazer (*Dactylagnus mundus*)	Dactyloscopidae	—	—	—	15.8	—	—	—	—	—	—
58232	Notchtail stargazer (*Dactyloscopus byersi*)	Dactyloscopidae	—	—	—	5.3	—	—	—	—	—	—
58234	Ornate stargazer (*Gillellus ornatus*)	Dactyloscopidae	—	—	—	5.3	—	—	—	—	—	—
60678	Longjaw stargazer (*Myxodagnus macrognathus*)	Dactyloscopidae	—	—	—	—	—	—	—	—	—	—
10206	Spotfin burrfish (*Chilomycterus reticulates*)	Diodontidae	—	—	—	57.9	—	—	—	—	—	—
3641	Pink seaperch (*Zalembius rosaceus*)	Embiotocidae	—	—	—	21.1	—	—	—	—	—	—
8289	Deepwater cornetfish (*Fistularia corneta*)	Fistulariidae	—	—	—	73.7	—	—	—	—	—	—
3080	Slender clingfish (*Rimicola eigenmanni*)	Gobiesocidae	—	—	—	6.0	—	—	—	—	—	—
11671	Southern clingfish (*R. dimorpha*)	Gobiesocidae	—	—	—	3.4	—	—	—	—	—	—
46927	Rosy clingfish (*Tomicodon eos*)	Gobiesocidae	—	—	—	4.2	—	—	—	—	—	—
46929	Cortez clingfish (*T. boehlkei*)	Gobiesocidae	—	—	—	6.8	—	—	—	—	—	—
54505	Tadpole clingfish (*Gobiesox pinniger*)	Gobiesocidae	—	—	—	10.7	—	—	—	—	—	—
55723	Smoothlip clingfish (*G. schultzi*)	Gobiesocidae	—	—	—	—	—	—	—	—	—	—
55746	Blackstripe clingfish (*Tomicodon myersi*)	Gobiesocidae	—	—	—	—	—	—	—	—	—	—
59749	Guadalupe clingfish (*Rimicola sila*)	Gobiesocidae	—	—	—	—	—	—	—	—	—	—
46803	Slow goby (*Aruma histrio*)	Gobiidae	—	—	—	6.8	—	—	—	—	—	—
46810	Saddlebanded goby (*Barbulifer mexicanus*)	Gobiidae	—	—	—	—	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5. NCN = no common name.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
46819	Panther goby (*Barbulifer pantherinus*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
53709	Tailspot goby (*Bollmannia stigmatura*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
53710	Frailscale goby (*B. macropoma*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
53711	NCN (*B. longipinnis*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
53713	Pennant goby (*B. ocellata*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
53714	NCN (*B. pawneea*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
54391	Enigmatic goby (*Evermannia longipinnis*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
54508	Shortjaw mudsucker (*Gillichthys seta*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
61016	Widebanded cleaning goby (*Elacatinus limbaughi*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
61322	Bright goby (*Ilypnus luculentus*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
509	Lingcod (*Ophiodon elongatus*)	Hexagrammidae	0.250	0.150	0.130	111.0	20	152.4	0.013	3.310	4.0	7.5
4036	Painted greenling (*Oxylebius pictus*)	Hexagrammidae	—	—	—	26.3	—	—	—	—	—	—
4038	Shortspine combfish (*Zaniolepis frenata*)	Hexagrammidae	0.400	—	0.270	25.0	—	—	—	—	—	—
13775	Tinsel squirrelfish (*Sargocentron suborbitalis*)	Holocentridae	—	—	—	26.7	—	—	—	—	—	—
46659	Sargassum blenny (*Exerpes asper*)	Labrisomidae	—	—	—	6.8	—	—	—	—	—	—
46691	Longjaw blenny (*Paraclinus tanygnathus*)	Labrisomidae	—	—	—	3.7	—	—	—	—	—	—
46699	Phallic blenny (*Starksia spinipenis*)	Labrisomidae	—	—	—	5.3	—	—	—	—	—	—
54352	Hidden blenny (*Cryptotrema seftoni*)	Labrisomidae	—	—	—	—	—	—	—	—	—	—
54354	Baja blenny (*Labrisomus wigginsi*)	Labrisomidae	—	—	—	—	—	—	—	—	—	—
54356	Pink blenny (*Paraclinus beebei*)	Labrisomidae	—	—	—	—	—	—	—	—	—	—
54360	Fugative blenny (*Starksia cremnobates*)	Labrisomidae	—	—	—	—	—	—	—	—	—	—
50720	Broadfin snailfish (*Paraliparis ulochir*)	Liparidae	—	—	—	10.7	—	—	—	—	—	—
59830	NCN (*Psednos pallidus*)	Liparidae	—	—	—	7.5	—	—	—	—	—	—
59831	NCN (*P. griseus*)	Liparidae	—	—	—	—	—	—	—	—	—	—
8465	Shoulderspot grenadier (*Caelorinchus scaphopsis*)	Macrouridae	—	—	—	35.8	—	—	—	—	—	—
59056	NCN (*Neoconger vermiformis*)	Moringuidae	—	—	—	—	—	—	—	—	—	—
2613	California moray (*Gymnothorax mordax*)	Muraenidae	—	—	—	160.0	26	152.0	0.000	3.430	—	—
13779	Hardtail moray (*Anarchias galapagensis*)	Muraenidae	—	—	—	14.7	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5. NCN = no common name.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
13784	Spottail moray (*Gymnothorax equatorialis*)	Muraenidae	—	—	—	78.9	—	—	—	—	—	—
13787	White-edged moray (*G. verrilli*)	Muraenidae	—	—	—	45.3	—	—	—	—	—	—
60962	NCN (*G. eurygnathos*)	Muraenidae	—	—	—	—	—	—	—	—	—	—
54067	Shorthead hagfish (*Eptatretus mcconnaugheyi*)	Myxinidae	—	—	—	49.5	—	—	—	—	—	—
54077	Cortez hagfish (*E. sinus*)	Myxinidae	—	—	—	50.6	—	—	—	—	—	—
11300	Palebelly searsid (*Barbantus curvifrons*)	Platytroctidae	—	—	—	13.8	—	—	—	—	—	—
59306	NCN (*Mentodus eubranchus*)	Platytroctidae	—	—	—	12.0	—	—	—	—	—	—
14156	Iguana lizardfish (*Synodus sechurae*)	Synodontidae	—	—	—	43.9	—	—	0.007	2.990	—	—
4292	Oceanic puffer (*Lagocephalus lagocephalus lagocephalus*)	Tetraodontidae	—	—	—	49.0	—	—	0.027	3.000	—	—
14173	Peruvian puffer (*Sphoeroides sechurae*)	Tetraodontidae	—	—	—	18.1	—	—	0.029	2.820	—	—
27212	Naked puffer (*S. lispus*)	Tetraodontidae	—	—	—	37.1	—	—	—	—	—	—
58978	NCN (*Lycenchelys folletti*)	Zoarcidae	—	—	—	16.6	—	—	—	—	—	—
46550	Cortez triplefin (*Axoclinus nigricaudus*)	Tripterygiidae	—	—	—	4.7	—	—	—	—	—	—
53712	Apostrophe goby (*Bollmannia marginalis*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
3573	Pacific porgy (*Calamus brachysomus*)	Sparidae	—	—	—	64.2	—	—	—	—	—	—
11800	Enigmatic tilefish (*Caulolatilus hubbsi*)	Malacanthidae	—	—	—	37.9	—	—	—	—	—	—
3711	Orangethroat pikeblenny (*Chaenopsis alepidota alepidota*)	Chaenopsidae	—	—	—	15.8	—	—	—	—	—	—
46825	Rubble goby (*Chriolepis minutillus*)	Gobiidae	—	—	—	3.4	—	—	—	—	—	—
46827	Gecko goby (*C. zebra*)	Gobiidae	—	—	—	4.6	—	—	—	—	—	—
25534	Redlight goby (*Coryphopterus urospilus*)	Gobiidae	—	—	—	6.8	—	—	—	—	—	—
46606	Lizard triplefin (*Crocodilichthys gracilis*)	Tripterygiidae	—	—	—	6.7	—	—	—	—	—	—
3861	Longtail goby (*Ctenogobius sagittula*)	Gobiidae	—	—	—	21.1	—	—	—	—	—	—
58233	Moonstruck stargazer (*Dactyloscopus lunaticus*)	Dactyloscopidae	—	—	—	—	—	—	—	—	—	—
54393	Silt goby (*Enypnias seminudus*)	Gobiidae	—	—	—	—	—	—	—	—	—	—
3854	Longjaw mudsucker (*Gillichthys mirabilis*)	Gobiidae	—	—	—	22.1	2	21.0	—	—	2.0	11.0
12229	Gulf opaleye (*Girella simplicidens*)	Kyphosidae	—	—	—	48.4	—	—	—	—	—	—
3076	Bearded clingfish (*Gobiesox papillifer*)	Gobiesocidae	—	—	—	6.0	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
46879	Crescent goby (*Gobulus crescentalis*)	Gobiidae	—	—	—	6.3	—	—	—	—	—	—
3707	Smooth stargazer (*Kathetostoma averruncus*)	Uranoscopidae	0.500	—	0.320	33.0	—	—	0.030	3.000	2.5	—
3596	Blue-bronze chub (*Kyphosus analogus*)	Kyphosidae	—	—	—	47.4	—	—	—	—	—	—
46663	Green blenny (*Labrisomus striatus*)	Labrisomidae	—	—	—	6.3	—	—	—	—	—	—
3885	Bluebanded goby (*Lythrypnus dalli*)	Gobiidae	—	—	—	6.7	—	—	—	—	—	—
46665	Fishgod blenny (*Malacoctenus ebisui*)	Labrisomidae	—	—	—	6.8	—	—	—	—	—	—
46741	Redside blenny (*M. hubbsi*)	Labrisomidae	—	—	—	9.5	—	—	—	—	—	—
46739	Margarita blenny (*M. margaritae*)	Labrisomidae	—	—	—	6.8	—	—	—	—	—	—
46674	Zaca blenny (*M. zacae*)	Labrisomidae	—	—	—	6.8	—	—	—	—	—	—
46679	Glossy blenny (*M. zonifer*)	Labrisomidae	—	—	—	8.4	—	—	—	—	—	—
46908	Roundscale goby (*Microgobius cyclolepis*)	Gobiidae	—	—	—	6.8	—	—	—	—	—	—
51436	Dart stargazer (*Myxodagnus opercularis*)	Dactyloscopidae	—	—	—		—	—	—	—	—	—
6414	Finespotted jawfish (*Opistognathus punctatus*)	Opistognathidae	—	—	—	42.0	—	—	0.015	3.000	—	—
46572	Giant jawfish (*O. rhomaleus*)	Opistognathidae	—	—	—	53.7	—	—	—	—	—	—
46689	Flapscale blenny (*Paraclinus sini*)	Labrisomidae	—	—	—	6.3	—	—	—	—	—	—
54506	Northern fraildisc clingfish (*Pherallodiscus funebris*)	Gobiesocidae	—	—	—	—	—	—	—	—	—	—
3896	Shadow goby (*Quietula y-cauda*)	Gobiidae	—	—	—	7.4	—	—	—	—	—	—
3598	Bluestriped chub (*Sectator ocyurus*)	Kyphosidae	—	—	—	62.1	—	—	—	—	—	—
4295	Longnose puffer (*Sphoeroides lobatus*)	Tetraodontidae	—	—	—	26.0	—	—	0.037	2.770	—	—
54361	Pinstriped blenny (*Starksia grammilaga*)	Labrisomidae	—	—	—	—	—	—	—	—	—	—
54362	Hose blenny (*S. hoesei*)	Labrisomidae	—	—	—	—	—	—	—	—	—	—
14155	Lance lizardfish (*Synodus scituliceps*)	Synodontidae	—	—	—	36.8	—	—	—	3.270	—	—
Pacific angel shark (FPS)			**0.170**	**0.043**	**0.157**	**126.0**	**35**	**119.7**	**0.009**	**3.122**	**10.5**	**300.0**
729	Pacific angel shark (*Squatina californica*)	Squatinidae	0.170	—	0.157	126.0	35	150.0	—	—	10.5	300.0
Small migratory sharks (FPO)			**0.330**	**0.165**	**0.270**	**115.0**	**11**	**109.3**	**0.002**	**3.190**	**3.0**	**90.0**
5940	Sharptooth smoothhound (*Mustelus dorsalis*)	Triakidae	—	—	—	67.4	—	—	—	—	—	—
2540	Brown smoothhound (*M. henlei*)	Triakidae	0.290	—	0.255	91.9	13	95.0	—	—	4.4	—
2541	Sicklefin smoothhound (*M. lunulatus*)	Triakidae	—	—	—	178.9	—	—	—	—	—	—
2538	Gray smoothhound (*M. californicus*)	Triakidae	0.370	—	0.285	122.0	9	160.0	0.002	3.190	1.6	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
Large pelagic sharks (FVB)			**0.182**	**0.046**	**0.112**	**346.3**	**27**	**329.0**	**0.012**	**2.928**	**10.0**	**30.0**
2534	Bigeye thresher shark (*Alopias superciliosus*)	Alopiidae	0.174	—	0.090	403.5	—	—	0.019	2.864	10.8	—
874	Blacktip shark (*Carcharhinus limbatus*)	Carcharhinidae	0.260	—	0.248	179.0	12	—	0.010	2.982	5.2	—
881	Smalltail shark (*C. porosus*)	Carcharhinidae	0.213	—	0.077	135.5	—	—	—	—	8.6	—
2532	Nurse shark (*Ginglymostoma cirratum*)	Ginglymostomatidae	0.226	—	0.141	449.0	25	—	0.018	2.876		—
5891	Pelagic thresher (*Alopias pelagicus*)	Alopiidae	0.232	—	0.102	189.5	—	—	0.018	2.588	8.1	—
2535	Thresher shark (*A. vulpinus*)	Alopiidae	0.230	1.000	0.100	651.0	15	610.0	0.019	2.519	6.0	—
873	Bull shark (*Carcharhinus leucas*)	Carcharhinidae	0.149	—	0.062	290.7	32	—	0.007	2.899	13.9	—
878	Dusky shark (*C. obscurus*)	Carcharhinidae	0.110	—	0.040	374.3	35	—	0.016	2.912	19.5	—
751	White shark (*Carcharodon carcharias*)	Lamnidae	0.120	—	0.062	598.5	36	600.0	0.011	3.044	10.3	—
752	Shortfin mako shark (*Isurus oxyrinchus*)	Lamnidae	0.160	1.000	0.180	322.7	25	380.0	0.017	2.875	5.5	—
901	Pacific sharpnose shark (*Rhizoprionodon longurio*)	Carcharhinidae	—	—	—	115.8	—	123.0	—	—	10.2	—
912	Scalloped hammerhead shark (*Sphyrna lewini*)	Sphyrnidae	0.130	—	0.133	287.0	35	—	0.006	3.075	12.5	—
914	Great hammerhead shark (*S. mokarran*)	Sphyrnidae	—	—	—	325.0	—	—	0.002	3.200	—	—
917	Smooth hammerhead (*S. zygaena*)	Sphyrnidae	—	—	—	526.3	—	—	0.001	3.300	—	—
Guitarfish (FVD)			**0.890**	**0.890**	**0.047**	**93.5**	**25**	**88.9**	**0.004**	**3.000**	**13.8**	**30.0**
2547	Thornback (*Platyrhinoidis triseriata*)	Rhinobatidae	—	—	—	95.8	—	—	—	—	—	—
2550	Banded guitarfish (*Zapteryx exasperate*)	Rhinobatidae	—	—	—	95.8	—	—	—	—	—	—
13234	Whitesnout guitarfish (*Rhinobatos leucorhynchus*)	Rhinobatidae	—	—	—	65.8	—	—	—	—	—	—
13229	Speckled guitarfish (*R. glaucostigma*)	Rhinobatidae	—	—	—	80.3	—	—	—	—	—	—
2549	Shovelnose guitarfish (*R. productus*)	Rhinobatidae	—	—	0.047	130.0	25	170.0	0.004	3.000	13.8	—
Skates, rays, and sharks (FVO)			**0.350**	**0.088**	**0.151**	**101.2**	**30**	**96.2**	**0.006**	**3.107**	**8.1**	**192.3**
2589	Spotted ratfish (*Hydrolagus colliei*)	Chimaeridae	0.460	—	0.209	87.5	—	—	—	—	—	—
7381	Whiptail stingray (*Dasyatis brevis*)	Dasyatidae	—	—	—	187.0	—	—	0.007	3.000	—	—
2578	California butterfly ray (*Gymnura marmorata*)	Gymnuridae	—	—	—	105.3	—	87.3	—	3.354	—	317.0
13183	Longsnout butterfly ray (*G. crebripunctata*)	Gymnuridae	—	—	—	32.6	—	—	—	—	—	—
739	Horn shark (*Heterodontus francisci*)	Heterodontidae	—	—	—	128.4	—	122.0	—	—	—	—
742	Mexican horn shark (*H. mexicanus*)	Heterodontidae	—	—	—	73.7	—	—	—	—	—	—
1250	Spotted eagle ray (*Aetobatus narinari*)	Myliobatidae	—	—	—	315.8	—	—	0.006	3.130	5.0	—
2582	Bat ray (*Myliobatis californica*)	Myliobatidae	0.353	—	0.164	129.5	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
2588	Smoothtail mobula (*Mobula thurstoni*)	Myliobatidae	—	—	—	231.6	—	—	—	—	—	—
8215	Giant electric ray (*Narcine entemedor*)	Narcinidae	—	—	—	80.2	—	—	—	—	—	—
8723	Bullseye electric ray (*Diplobatis ommata*)	Narcinidae	—	—	—	26.3	—	—	—	—	—	—
769	Longnose cat shark (*Apristurus kampae*)	Scyliorhinidae	—	—	—	61.5	—	—	—	—	—	—
802	Swell shark (*Cephaloscyllium ventriosum*)	Scyliorhinidae	—	—	—	105.3	—	100.0	—	—	—	—
2543	Leopard shark (*Triakis semifasciata*)	Triakidae	0.140	—	0.081	155.0	30	198.0	0.003	3.050	16.0	—
2580	Round stingray (*Urobatis halleri*)	Urolophidae	0.448	—	0.152	46.0	—	—	0.007	3.000	—	—
8218	Blotched stingray (*Urotrygon chilensis*)	Urolophidae	—	—	—	44.1	—	—	—	—	—	—
13274	Reef stingray (*Urobatis concentricus*)	Urolophidae	—	—	—	50.0	—	—	—	—	—	—
13276	Cortez stingray (*U. maculates*)	Urolophidae	—	—	—	44.2	—	—	—	—	—	—
13285	Thorn stingray (*Urotrygon rogersi*)	Urolophidae	—	—	—	48.6	—	—	—	—	—	—
2573	Diamond stingray (*Dasyatis dipterura*)	Dasyatidae	—	—	—	128.4	—	—	—	—	3.2	67.5
13199	Longnose eagle ray (*Myliobatis longirostris*)	Myliobatidae	—	—	—	100.0	—	—	—	—	—	—
8217	Equatorial skate (*Raja equatorialis*)	Rajidae	—	—	—	52.6	—	—	—	—	—	—
13271	Golden cownose (*Rhinoptera steindachneri*)	Myliobatidae	—	—	—	94.7	—	—	—	—	—	—
Flatfish (FVS)			**1.684**	**0.421**	**0.976**	**28.1**	**12**	**26.7**	**0.009**	**3.122**	**1.5**	**38.5**
10429	Pacific lined sole (*Achirus mazatlanus*)	Achiridae	2.013	—	1.092	20.9	—	—	0.013	3.078	—	—
13434	Network sole (*A. scutum*)	Achiridae	—	—	—	20.0	—	—	—	—	—	—
13441	Spotted fin sole (*Trinectes fonsecensis*)	Achiridae	—	—	—	19.5	—	—	—	—	—	—
8274	Pacific eyed flounder (*Bothus constellatus*)	Bothidae	—	—	—	16.5	—	—	—	—	—	—
13556	Pacific leopard flounder (*B. leopardinus*)	Bothidae	—	—	—	15.8	—	—	—	—	—	—
13563	Flag flounder (*Perissias taeniopterus*)	Bothidae	—	—	—	11.6	—	—	—	—	—	—
4262	California tonguefish (*Symphurus atricaudus*)	Cynoglossidae	—	—	—	22.1	—	—	—	—	—	—
13632	Halfspotted tonguefish (*S. atramentatus*)	Cynoglossidae	—	—	—	15.2	—	—	—	—	—	—
13636	Chocolate tonguefish (*S. callopterus*)	Cynoglossidae	—	—	—	17.1	—	—	—	—	—	—
13637	Darkcheek tonguefish (*S. chabanaudi*)	Cynoglossidae	—	—	—	24.5	—	—	—	—	—	—
13643	Banded tonguefish (*S. fasciolaris*)	Cynoglossidae	—	—	—	17.1	—	—	—	—	—	—
13644	Dwarf tonguefish (*S. gorgonae*)	Cynoglossidae	—	—	—	8.6	—	—	—	—	—	—
13645	Blacktail tonguefish (*S. leei*)	Cynoglossidae	—	—	—	15.6	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
13646	Drab tonguefish (*S. melanurus*)	Cynoglossidae	—	—	—	19.6	—	—	—	—	—	—
13649	Whitetail tonguefish (*S. oligomerus*)	Cynoglossidae	—	—	—	15.4	—	—	—	—	—	—
13650	Halfstriped tonguefish (*S. prolatinaris*)	Cynoglossidae	—	—	—	16.9	—	—	—	—	—	—
13655	Yellow tonguefish (*S. williamsi*)	Cynoglossidae	—	—	—	12.2	—	—	—	—	—	—
24626	Elongate tonguefish (*S. elongatus*)	Cynoglossidae	—	—	—	16.6	—	—	—	—	—	—
13969	Cortez halibut (*Paralichthys aestuarius*)	Paralichthyidae	—	—	—	61.4	—	—	—	—	—	—
58221	Five-rayed sanddab (*Citharichthys mariajorisae*)	Paralichthyidae	—	—	—	13.0	—	—	—	—	—	—
8225	Three spot sand flounder (*Ancylopsetta dendritica*)	Paralichthyidae	—	—	—	36.8	—	—	—	—	—	—
4212	Gulf sanddab (*Citharichthys fragilis*)	Paralichthyidae	—	—	—	23.2	—	—	—	—	—	—
4217	Speckled sanddab (*C. stigmaeus*)	Paralichthyidae	—	—	—	17.9	4	17.0	0.000	3.295	—	—
4218	Longfin sanddab (*C. xanthostigma*)	Paralichthyidae	—	—	—	26.3	—	—	—	—	—	—
4221	Fringed flounder (*Etropus crossotus*)	Paralichthyidae	2.816	—	1.745	18.7	1	—	0.007	3.140	0.4	—
13965	Spotted flounder (*Hippoglossina bollmani*)	Paralichthyidae	—	—	—	—	—	—	—	—	—	—
4225	Bigmouth sole (*H. stomata*)	Paralichthyidae	—	—	—	42.1	—	—	—	—	—	—
4228	California halibut (*Paralichthys californicus*)	Paralichthyidae	0.225		0.090	118.3	30	152.4	0.008	3.071	2.5	38.5
13971	Dappled flounder (*P. woolmani*)	Paralichthyidae	—	—	—	84.2	—	—	—	—	—	—
13979	Ocellated turbot (*Pleuronichthys ocellatus*)	Pleuronectidae	—	—	—	25.3	—	—	—	—	—	—
4254	Hornyhead turbot (*P. verticalis*)	Pleuronectidae	—	—	—	38.9	—	37.0	—	—	—	—
13978	Oval flounder (*Syacium ovale*)	Paralichthyidae	—	—	—	24.2	—	—	—	3.150	—	—
4235	Fantail sole (*Xystreurys liolepis*)	Paralichthyidae	—	—	—	63.5	—	—	0.016	3.000	—	—
Mojarra (FVT)			**3.395**	**3.395**	**0.813**	**19.4**	**15**	**9.3**	**0.017**	**3.059**	**1.8**	**30.0**
1054	Yellowfin mojarra (*Gerres cinereus*)	Gerreidae	1.278	—	0.625	29.0	—	10.2	0.012	2.974	—	—
10430	Peruvian mojarra (*Diapterus peruvianus*)	Gerreidae	5.512	—	—	11.9	—	8.9	0.013	3.322	—	—
13697	Black axillary mojarra (*Eugerres axillaris*)	Gerreidae	—	—	1.000	20.0	—	—	—	—	—	—
13728	Pacific flagfin mojarra (*Eucinostomus currani*)	Gerreidae	—	—	—	20.9	—	7.6	0.027	2.750	—	—
13729	Darkspot mojarra (*E. entomelas*)	Gerreidae	—	—	—	18.9	—	10.6	0.018	3.190	—	—
13696	Golden mojarra (*Diapterus aureolus*)	Gerreidae	—	—	—	15.8	—	—	—	—	—	—
Scorpionfish (FVV)			**1.042**	**0.261**	**0.477**	**23.5**	**21**	**22.3**	**0.018**	**2.980**	**2.7**	**45.0**

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5. NCN = no common name.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
8222	Speckled scorpionfish (*Pontinus sierra*)	Scorpaenidae	—	—	—	11.0	—	—	0.018	2.840	—	—
14222	Sonora scorpionfish (*Scorpaena sonorae*)	Scorpaenidae	—	—	—	16.6	—	—	—	—	—	—
4015	Splitnose searobin (*Bellator xenisma*)	Triglidae	—	—	—	11.6	—	—	—	—	—	—
4029	Lumptail searobin (*Prionotus stephanophrys*)	Triglidae	0.564	—	0.196	36.4	—	—	0.016	2.966	4.3	—
14255	Chevron searobin (*Bellator loxias*)	Triglidae	—	—	—	15.8	—	—	—	—	—	—
14256	Whitesnout searobin (*Prionotus albirostris*)	Triglidae	1.976	—	1.021	19.1	—	—	0.019	3.049	—	—
14257	Twobeak searobin (*P. birostratus*)	Triglidae	—	—	—	18.9	—	—	—	—	—	—
14259	Rough searobin (*P. ruscarius*)	Triglidae	—	—	—	39.5	—	—	0.016	2.930	—	—
3943	California scorpionfish (*Scorpaena guttata*)	Scorpaenidae	0.587	—	0.213	38.4	21	43.0	0.021	3.005	1.0	45.0
8332	Player scorpionfish (*S. histrio*)	Scorpaenidae	—	—	—	18.4	—	—	—	—	—	—
8333	Stone scorpionfish (*S. mystes*)	Scorpaenidae	—	—	—	48.1	—	—	—	—	—	—
1201	Spotted scorpionfish (*S. plumieri*)	Scorpaenidae	—	—	—	24.1	—	—	0.020	3.120	—	—
14220	Reddish scorpionfish (*S. russula*)	Scorpaenidae	—	—	—	15.0	—	—	0.019	2.950	—	—
3948	Rainbow scorpionfish (*Scorpaenodes xyris*)	Scorpaenidae	—	—	—	15.8	—	—	—	—	—	—
Lanternfish and deep (SHB)			**0.533**	**0.133**	**0.383**	**15.1**	**8**	**14.4**	**0.011**	**2.884**	**4.0**	**30.0**
2739	Mexican lampfish (*Triphoturus mexicanus*)	Myctophidae	—	—	—	7.4	—	—	—	—	—	—
50707	Lamp fish (*Benthosema panamense*)	Myctophidae	—	—	—	5.8	—	—	—	—	—	—
54417	Slimtail lampfish (*Lampanyctus parvicauda*)	Myctophidae	—	—	—	—	—	—	—	—	—	—
3096	Rounded batfish (*Zalieutes elater*)	Ogcocephalidae	0.400	—	0.300	15.0	—	—	—	—	—	—
58630	NCN (*Dibranchus hystrix*)	Ogcocephalidae	—	—	—	13.2	—	—	—	—	—	—
58635	NCN (*D. spinosus*)	Ogcocephalidae	—	—	—	15.7	—	—	—	—	—	—
2714	Pacific viperfish (*Chauliodus macouni*)	Stomiidae	0.500	—	0.350	23.0	8	—	0.005	2.884	—	—
5155	Black-belly dragonfish (*Stomias atriventer*)	Stomiidae	0.700	—	0.500	26.0	—	—	—	—	—	—
46954	Scaleless dragonfish (*Bathophilus filifer*)	Stomiidae	—	—	—	—	—	—	—	—	—	—
Totoaba (SHC)			**0.268**	**0.066**	**0.152**	**169.9**	**15**	**161.4**	**0.040**	**2.590**	**6.5**	**30.0**
6317	Totoaba (*Totoaba macdonaldi*)	Sciaenidae	0.268	0.066	0.152	169.9	15	200.0	0.040	2.590	6.5	—
Large pelagics (SHD)			**1.063**	**1.063**	**0.468**	**125.6**	**17**	**102.3**	**0.020**	**2.991**	**3.9**	**52.5**
998	Pilotfish (*Naucrates doctor*)	Carangidae	6.071	—	—	29.0	4	—	0.015	3.040	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
1900	Green jack (*Caranx caballus*)	Carangidae	—	—	—	48.3	—	—	0.025	3.000	—	—
1901	Pacific crevalle jack (*C. caninus*)	Carangidae	—	—	—	91.0	—	—	0.016	3.000	—	—
1915	Threadfin jack (*Carangoides otrynter*)	Carangidae	—	—	—	52.6	—	—	—	—	—	—
1917	Bigeye trevally (*Caranx sexfasciatus*)	Carangidae	0.517		0.240	80.0	—	—	0.028	2.836	—	—
1919	Cocinero (*C. vinctus*)	Carangidae	—	—	—	36.8	—	—	—	—	—	—
1937	Pacific bumper (*Chloroscombrus orqueta*)	Carangidae	—	—	—	31.6	—	—	—	—	—	—
1938	Shortfin scad (*Decapterus macrosoma*)	Carangidae	2.020	—	0.973	26.9	—	—	0.007	3.109	—	—
1943	Yellowfin jack (*Hemicaranx leucurus*)	Carangidae	—	—	—	31.6	—	—	—	—	—	—
1944	Blackfin jack (*H. zelotes*)	Carangidae	—	—	—	26.3	—	—	—	—	—	—
1969	Blackblotch pompano (*Trachinotus kennedyi*)	Carangidae	—	—	—	71.6	—	—	—	—	—	—
1972	Paloma pompano (*T. paitensis*)	Carangidae	—	—	—	53.7	—	—	—	—	—	—
1973	Gafftopsail pompano (*T. rhodopus*)	Carangidae	—	—	—	36.8	—	—	0.025	3.000	—	—
4464	Golden trevally (*Gnathanodon speciosus*)	Carangidae	0.624	—	0.335	88.5	—	—	0.043	2.843	—	—
6	Dolphinfish (*Coryphaena hippurus*)	Coryphaenidae	0.870	—	1.633	159.6	5	—	0.026	2.846	0.5	—
1751	Remora (*Remora remora*)	Echeneidae	—	—	—	63.5	—	—	0.004	3.000	—	—
2601	Machete (*Elops affinis*)	Elopidae	—	—	—	95.8	—	—	—	—	—	—
1072	Opah (*Lampris guttatus*)	Lampridae	—	—	—	106.5	—	—	0.041	3.000	—	—
1732	Ocean sunfish (*Mola mola*)	Molidae	0.409	—	0.310	336.0	—	—	0.045	3.050	—	—
1750	Slender mola (*Ranzania laevis*)	Molidae	—	—	—	105.3	—	—	—	—	—	—
13806	Charcoal codling (*Physiculus nematopus*)	Moridae	—	—	—	27.4	—	—	—	—	—	—
2081	Whale shark (*Rhincodon typus*)	Rhincodontidae	0.064	—	0.036	1683.0	—	—	0.004	3.000	15.7	—
244	Chinook salmon (*Oncorhynchus tshawytscha*)	Salmonidae	—	—	—	149.0	9	—	0.013	3.000	4.5	—
107	Skipjack tuna (*Katsuwonus pelamis*)	Scombridae	1.275	—	0.629	85.0	12	—	0.005	3.291	1.5	—
54674	Bullet mackerel (*Auxis rochei eudorax*)	Scombridae	—	—	—	38.4	—	—	—	—	—	—
54675	Frigate mackerel (*A. thazard brachydorax*)	Scombridae	—	—	—	42.1	—	—	—	—	—	—
12007	Cortez barracuda (*Sphyraena lucasana*)	Sphyraenidae	—	—	—	73.7	—	—	—	—	—	—
14142	Cortez butterfish (*Peprilus ovatus*)	Stromateidae	—	—	—	21.1	—	—	—	—	—	—
14146	Salema butterfish (*P. snyderi*)	Stromateidae	—	—	—	31.6	—	28.0			2.1	—
226	Swordfish (*Xiphias gladius*)	Xiphiidae	0.200	—	0.173	271.6	—	—	0.004	3.295	5.5	—
98	Black skipjack (*Euthynnus lineatus*)	Scombridae	—	—	—	88.4	—	—	0.024	3.018	—	—
1945	Longjaw leatherjack (*Oligoplites altus*)	Carangidae	—	—	—	55.0	—	—	0.009	3.000	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
113	Pacific bonito (*Sarda chiliensis chiliensis*)	Scombridae	0.587	—	0.305	88.5	—	—	0.012	3.053	2.0	—
382	Yellowtail jack (*Seriola lalandi*)	Carangidae	0.940	—	0.136	136.6	64	66.0	0.054	2.740	2.0	45.0
1007	Almaco jack (*S. rivoliana*)	Carangidae		—	—	59.5	12	193.0	0.010	3.113	—	60.0
6405	Mexican barracuda (*Sphyraena ensis*)	Sphyraenidae	0.183	—	0.249	127.0	12	122.0	0.005	3.000	1.5	—
412	Rainbow runner (*Elagatis bipinnulata*)	Carangidae	0.887	—	0.600	97.5	—	—	0.018	2.580	—	—
Mackerel (SHP)			**0.443**	**0.222**	**0.311**	**69.4**	**19**	**65.9**	**0.012**	**3.014**	**2.0**	**30.0**
368	Jack mackerel (*Trachurus symmetricus*)	Carangidae	0.150	—	0.328	65.1	30	—	0.008	3.103	3.0	—
1041	Snake mackerel (*Gempylus serpens*)	Gempylidae	—	—	—	58.0	—	—	0.001	3.000	—	—
122	Gulf sierra (*Scomberomorus concolor*)	Scombridae	0.630	—	0.360	81.1	—	77.0	0.037	2.685	1.3	—
117	Pacific chub mackerel (*Scomber japonicus*)	Scombridae	0.550	—	0.323	43.9	18	64.0	0.007	3.284	2.5	—
136	Pacific sierra (*Scomberomorus sierra*)	Scombridae	—	—	0.233	99.0	—	100.9	0.008	3.000	1.0	—
Hake (SHR)			**0.840**	**0.420**	**0.343**	**35.4**	**9**	**33.6**	**0.015**	**2.781**	**2.2**	**30.0**
1827	Panama hake (*Merluccius angustimanus*)	Merlucciidae	0.840	—	0.343	35.4	—	61.2	0.015	2.781	2.2	—
60857	Cortez hake (*M. hernandezi*)	Merlucciidae	—	—	—	—	—	—	—	—	—	—
Small pelagics (SSK)			**1.571**	**0.393**	**0.930**	**17.4**	**9**	**16.5**	**0.011**	**3.031**	**1.9**	**36.0**
2699	Pacific argentine (*Argentina sialis*)	Argentinidae	0.870	—	0.540	22.0	5	—	0.010	3.000	—	—
3235	Topsmelt (*Atherinops affinis*)	Atherinopsidae	—	—	—	38.9	7	—	0.010	3.000	2.0	—
6285	False grunion (*Colpichthys regis*)	Atherinopsidae	—	—	—	—	10	48.6	0.010	3.000	2.5	35.0
13511	Longfin silverside (*Atherinella eriarcha*)	Atherinopsidae	—	—	—	8.4	10	48.6	0.010	3.000	2.5	35.0
13515	Pitcher silverside (*A. nepenthe*)	Atherinopsidae	—	—	—	10.5	3	—	0.010	3.000	2.0	35.0
13521	Delta silverside (*Colpichthys hubbsi*)	Atherinopsidae	—	—	—	15.8	3	—	0.010	3.000	2.0	35.0
13523	Gulf grunion (*Leuresthes sardine*)	Atherinopsidae	—	—	—	26.3	4	19.0	0.009	3.000	1.0	40.0
2703	California smoothtongue (*Leuroglossus stilbius*)	Bathylagidae	—	—	—	15.8	—	15.0	—	—	—	—
1477	Pacific sardine (*Sardinops sagax*)	Clupeidae	0.416	—	0.485	26.7	25	39.0	0.012	3.109	1.9	
1481	Flatiron herring (*Harengula thrissina*)	Clupeidae	—	—	—	13.2	—	—	—	—	—	—
1484	Deepbody thread herring (*Opisthonema libertate*)	Clupeidae	1.106	—	0.466	24.6	—	—	0.020	2.990	—	—
1529	Striped herring (*Lile stolifera*)	Clupeidae	2.571	—	1.356	14.4	19	46.0	0.008	3.199	—	—
1644	Yellowfin herring (*Pliosteostoma lutipinnis*)	Clupeidae	—	—	—	18.9	—	—	—	—	—	—
1648	Dove's longfin herring (*Opisthopterus dovi*)	Clupeidae	—	—	—	20.6	—	—	—	—	—	—
279	Short anchovy (*Anchoa curta*)	Engraulidae	0.900	—	0.600	6.7	7	24.8	0.012	2.950	2.0	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
542	Persistent anchovy (*Anchoa walkeri*)	Engraulidae	—	—	—	12.6	—	—	—	—	—	—
544	Bigscale anchovy (*Anchovia macrolepidota*)	Engraulidae	—	—	—	15.8	—	—	—	3.260	—	—
548	Anchoveta (*Cetengraulis mysticetus*)	Engraulidae	2.400	—	1.988	15.6	3	—	—	—	1.0	—
570	Northern gulf anchovy (*Anchoa mundeoloides*)	Engraulidae	—	—	—	12.6	—	12.8	0.016	2.940	—	—
730	False Panama anchovy (*A. mundeola*)	Engraulidae	0.736	—	0.207	16.0	—		0.007	3.019	—	—
1127	Sharpnose anchovy (*A. ischana*)	Engraulidae	—	—	—	12.6	—	9.2	0.007	3.000	—	—
1137	Slender anchovy (*A. exigua*)	Engraulidae	—	—	—	6.3	—	—	—	—	—	—
1163	Bignose anchovy (*A. nasus*)	Engraulidae	3.574	—	1.800	8.6	—	—	—	—	—	—
1680	Silverstripe anchovy (*A. argentivittata*)	Engraulidae	—	—	—	10.5	—	—	—	—	—	—
1689	Gulf anchovy (*A. helleri*)	Engraulidae	—	—	—	8.9	—	—	—	—	—	—
13682	California flyingfish (*Cheilopogon pinnatibarbatus californicus*)	Exocoetidae	—	—	—	40.0	—	—	—	—	—	—
13691	Beautyfin flyingfish (*Cypselurus callopterus*)	Exocoetidae	—	—	—	29.5	—	—	—	—	—	—
Mysticeti (WHB)			**0.044**	**0.000**	**0.243**	**2,590.5**	**88**	**2,355.0**	**0.003**	**3.000**	**7.3**	**356.3**
	Brydes whale (*Balaenoptera edeni*)	Balaenopteridae	—	—	0.330	—	—	—	—	—	—	—
	Fin whale (*B. physalus*)	Balaenopteridae	—	—	0.154	2,200.0	98	2,700.0	0.001	2.329	7.0	—
	Blue whale (*B. musculus*)	Balaenopteridae	—	—	—	2,600.0	100	3,360.0	0.001	2.329	9.0	—
	Gray whale (*Eschrichtius robustus*)	Eschrichtiidae	—	—	0.246	1,300.0	80	1,500.0	0.001	2.329	8.0	—
	Humpback whale (*Megaptera novaeangliae*)	Balaenopteridae	0.044	—	—	1,500.0	75	1,860.0	0.001	2.329	5.0	—
Odontocetae (WHT)			**0.083**	**0.000**	**0.160**	**685.1**	**45**	**622.9**	**0.030**	**3.000**	**8.7**	**392.1**
	Long-beaked common dolphin (*Delphinus capensis*)	Dephinidae	—	—	—	218.0	22	230.0	0.000	2.382	7.0	—
	Common dolphin (*D. delphis*)	Dephinidae	—	—	—	185.0	22	200.0	0.000	2.382	7.0	—
	Bottlenose dolphin (*Tursiops truncates*)	Dephinidae	—	—	—	340.0	47	380.0	0.000	2.382	9.0	—
	Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)		—	—	—	181.2	38	240.0	0.000	2.382	8.0	—
	Baird's beaked whale (*Berardius bairdii*)	Ziphiidae	—	—	—	1,025.0	70	1,200.0	0.000	2.382	12.0	—
	Sperm whale (*Physeter macrocephalus*)	Physeteridae	0.083	—	0.160	1,600.0	69	1,500.0	0.000	2.382	9.0	—
	Short-finned pilot whale (*Globicephala macrorhynchus*)	Dephinidae	—	—	—	570.0	45	610.0	0.000	2.382	9.0	—
	False killer whale (*Pseudorca crassidens*)	Dephinidae	—	—	—	—	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
	Pygmy beaked whale (*Mesoplodon peruvianus*)	Ziphiidae	—	—	—	—	—	—	—	—	—	—
Orca (WHS)			**0.010**	**0.000**	**0.100**	**1,000.0**	**50**	**915.0**	**0.002**	**3.000**	**13.0**	**480.0**
	Orca (*Orcinus orca*)	Dephinidae	0.010	—	0.100	1,000.0	50	915.0	0.000	2.382	13.0	—
Vaquita (WDG)			**0.010**	**0.062**	**0.200**	**176.0**	**21**	**160.0**	**0.004**	**3.000**	**10.0**	**330.0**
	Vaquita (*Phocoena sinus*)	Phocoenidae	—	0.062	0.200	—	21	160.0	0.001	3.532	10.0	—
Pinnipeds (PIN)			**0.250**	**0.005**	**0.392**	**333.7**	**18**	**303.3**	**0.002**	**3.000**	**4.5**	**360.0**
	Elephant seal (*Mirounga angustirostris*)	Phocidae	0.250	—	0.392	263.3	15	303.3	0.001	3.532	—	—
	California sea lion (*Zalophus californianus*)	Otariidae	—	0.005	—	190.0	20	206.7	—	3.532	4.5	—
Oceanic sea turtles (SP)			**0.149**	**0.000**	**0.072**	**200.0**	**60**	**125.0**	**0.027**	**3.000**	**11.5**	**59.5**
	Leatherback turtle (*Dermochelys coriacea*)	Dermochelyidae	0.149	—	0.072	200.0	—	180.0	—	—	11.5	—
	Olive Ridley turtle (*Lepidochelys olivacea*)	Cheloniidae	—	—	—	—	—	70.0	—	—	—	—
Reef associated turtles (REP)			**0.016**	**0.000**	**0.072**	**120.1**	**60**	**108.1**	**0.083**	**3.000**	**15.0**	**45.8**
	Loggerhead turtle (*Caretta caretta*)	Cheloniidae	—	—	0.076	111.9	—	100.7	—	—	18.0	18.0
	Hawksbill turtle (*Eretmochelys imbricata*)	Cheloniidae	—	—	—	—	—	—	—	—	—	—
	Green turtle (*Chelonia mydas*)	Cheloniidae	0.016	—	0.068	128.3	—	115.4	—	—	22.5	—
Sea birds (SB)			**0.177**	**0.000**	**0.033**	**14.2**	**28**	**12.8**	**0.001**	**3.000**	**4.2**	**21.0**
	Blue-footed booby (*Sula nebouxii*)	Sulidae	—	—	—	—	—	—	—	—	—	—
	Brown booby (*S. leucogaster*)	Sulidae	—	—	—	—	—	—	—	—	—	—
	Heermann's gull (*Larus heermanni*)	Laridae	—	—	—	—	—	—	—	—	—	—
	California gull (*L. californicus*)	Laridae	0.135	—	—	—	30	—	—	—	4.0	—
	Yellow-footed gull (*L. livens*)	Laridae	—	—	—	—	—	—	—	—	—	—
	Elegant tern (*Thalasseus elegans*)	Laridae	—	—	—	—	—	—	—	—	—	—
	Royal tern (*T. maximus*)	Laridae	—	—	—	—	—	—	—	—	—	—
	Forster's tern (*Sterna forsteri*)	Laridae	—	—	—	—	—	—	—	—	—	—
	Black storm-petral (*Oceanodroma melania*)	Hydrobatidae	0.151	—	—	—	36	—	—	—	5.0	—
	Least storm-petral (*Halocyptena microsoma*)	Hydrobatidae	—	—	—	—	—	—	—	—	—	—
	Brandt's cormorant (*Phalacrocorax penicillatus*)	Phalacrocoracidae	0.301	—	—	—	18	—	—	—	3.0	—
	Double-crested cormorant (*P. auritus*)	Phalacrocoracidae	—	—	—	—	—	—	—	—	—	—
	Magnificent frigatebird (*Fregata magnificens*)	Fregatidae	—	—	0.018	14.2	—	—	—	—	—	—

Table A-3 continued. Life history data. Data points are referenced in Table A-4 with full citations in Table A-5.

Fish Base code	Common and scientific names	Family	M	F	k	L∞	Tmax (years)	Lmax (cm)	a	b	Mature (years)	Larval duration (days)
	American oystercatcher (*Haematopus palliates*)	Haematopodidae	—	—	—	—	—	—	—	—	—	—
	Snowy egret (*Egretta thula*)	Ardeidae	—	—	—	—	—	—	—	—	—	—
	Reddish egret (*E. rufescens*)	Ardeidae	—	—	—	—	—	—	—	—	—	—
	Great egret (*Ardea alba*)	Ardeidae	—	—	—	—	—	—	—	—	—	—
	Great blue heron (*A. herodias*)	Ardeidae	—	—	—	—	—	—	—	—	—	—
	Whimbrel (*Numenius phaeopus*)	Scolopacidae	—	—	—	—	—	—	—	—	—	—
	Least sandpiper (*Calidris minutilla*)	Scolopacidae	—	—	—	—	—	—	—	—	—	—
	Black turnstone (*Arenaria melanocephala*)	Scolopacidae	—	—	—	—	—	—	—	—	—	—
	Brown pelican (*Pelecanus occidentalis*)	Pelecanidae	0.223	—	—	—	28	—	—	—	3.0	—
	Sooty shearwater (*Puffinus griseus*)	Procellariidae	0.074	—	0.049	—	26	—	—	—	6.0	—
	Flesh-footed shearwater (*P. carneipes*)	Procellariidae	—	—	—	—	—	—	—	—	—	—
	Eared grebe (*Podiceps nigricollis*)	Podicipedidae	—	—	—	—	—	—	—	—	—	—
	Craveri's murrelet (*Synthliboramphus craveri*)	Alcidae	—	—	—	—	—	—	—	—	—	—

Table A-4. Life history parameter references (numbers keyed to Table A-5).

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Gulf coney (FBP)								
Gulf coney				187		171,187,354	118	1
Extranjero (FDB)								
Parrot sand bass			24	189		1,24	24	1
Spotted sand bass				198			118	
Leopard grouper (FDC)								
Leopard grouper			126	198		198,362,416	118	1,138
Gulf grouper (FDD)								
Gulf grouper				113		1,363	113	363
Amarillo snapper (FDE)								
Yellow snapper	107,465		107	107		106,115,356,426	113,115,356,426	115
Barred pargo (FDF)								
Barred pargo				113		9	113,118	
Groupers and snappers (FDM)								
Threadfin bass				140		174	174	
Splittail bass				189				
Panama graysby	111		111	111			111	
Highfin sand perch				360			360	
Bigeye bass				189				
Deepwater serrano								
Scalyfin basslet								
Pacific mutton hamlet				187				
Bighead sand perch				360			360	
Mexican sand perch				189				
Pacific sand perch				189				
Squirrel sand perch				189				
Mutton hamlet				187				
Spotted cabrilla				113			113	
Leather bass				198			198	
Goliath grouper	53		53	53			53	
Flag cabrilla	111,357		111,357	111,357			111,357	
Rivulated mutton hamlet				187				
Star-studded grouper				187				
Snowy grouper	262,287		262,287	262,287	257		18,183,262	347
Mullet snapper				198			198	
Colorado snapper				113			113	
Spotted rose snapper				198			198	
Pacific snapper				113			113	
Pacific red snapper	22,369		22	369		22	118	
Blue-and-gold snapper				7				
Sawtail grouper				198			198	

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5).

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Broom-tail grouper				113			113	
Spotted sand bass	198		47	198	47	47	198	47
Pacific creolefish				418				
Pacific reef bass				341				
Mottled soapfish				196				
Twice-spotted soapfish				418				
Blacktip grouper				417				
Barred serrano				189				
Drums and croakers (FDO)								
White seabass	413		413	413	252	251	413	330,439
Bairdiella				76				
Black croaker	321		321	321				248,321
Shortfin corvina				198			198	
Yellowfin croaker				198	252	251	198	252,265,384
Dusky croaker				76				
Yelloweye croaker				76				
Gulf croaker				76		353	353	12,71
Slender croaker				76				
Golden croaker				76				
Highfin kingfish				76				
Shining drum				76				
Silver drum				76				
Steeplined drum				76				
Bigeye corvina				76				
Bluestreak drum				76				
Gulf corvina				198			118	
Dwarf corvina				360			360	
Squint-eyed croaker				76				
Silver stardrum				76				
Cortez drum				76				
Surf croaker				76				
Vacuocua croaker				360			360	
Scalyfin corvina				76				
Armed croaker				76				
Striped corvina				198			198	
Orangemouth corvina	444		444	444			444	
Pacific drum				76				
California corbina	437		437	437	151,265	251	113	384
Grunts (FDP)								
Burrito grunt	116		116	116			116	
Armed grunt				275				

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5). NCN = no common name.

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Silvergray grunt				275				
Sargo				140				
Blackbarred grunt				74				
Pacific porkfish				275		174	174	
Cortez grunt	116		116	116			116	
Spottail grunt	116		116	116		174	116,360	
Mojarra grunt				275				
Graybar grunt	116		116	116			116	
Latin grunt				166		174	166	
Wavyline grunt				360	151,252	254,275	360	144
Humpback grunt				275		174	174	
Bronzestriped grunt	116		116	116			116	
Panamic grunt				275		174	2,174	
Salema				275		254,282		
Herbivorous fish (FDS)								
Yellowfin surgeonfish				242			242	
Yellowtail surgeonfish				225				
Achilles tang				320			320	
Goldrim surgeonfish				342			385	
Spinytooth parrotfish	38,294		38,294	38,294			220,294	
Opaleye				140				
Zebraperch				396		251		
Striped mullet	15,67,128,139, 143,199,204, 321,322,420, 421,453		15,67,128, 139,143,199, 204,321,322, 453	15,67,128,139, 143,199,204, 321,322,453	302,420,422	254,419	15,67,108,128, 134,215,232, 242,340,427	266
White mullet	434,444		434,444	434,444		174,197	87,167,215,444	164
Loosetooth parrotfish				37				
Azure parrotfish				37				
Bluechin parrotfish	177,294		177,294	177,294	177		242,294	
Bumphead parrotfish				418				
Bicolor parrotfish	177		177	177	177		385	
Large reef fish (FMM)								
Convict surgeon	294,321		294,321	294,321			242,294,385	
Finescale triggerfish				140		28	28	
Blunthead triggerfish				57				
Orangeside triggerfish				57				
NCN (*Chlopsis kazuko*)				237				
Peppered garden eel				388				
Cape garden eel				388				
Cortez garden eel				388				

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5). NCN = no common name.

Name	**M**	**F**	**k**	**L∞**	**Tmax (years)**	**Lmax (cm)**	**a/b**	**Mature (years)**
Sharpnose conger				196				
Shorttail conger				388				
Ringeye conger				388				
Shorthead conger				388				
Largehead conger				388				
Hardtail conger				140				
Needletail conger				388				
Cortez rainbow wrasse				172				
NCN (*Nemichthys larseni*)				387				
Tiger snake eel				297				
Pacific worm eel				140				
Pacific snake eel				140				
Yellow snake eel	149		149	149			149	
Sandy ridgefin eel				268				
Spotted ridgefin eel				268				
Ordinary eel				268				
NCN (*Apterichtus gymnocelus*)								
Pacific bearded brotula								
Finescale cusk-eel				238				
Specklefin cusk-eel				238				
Leopard cusk-eel				238				
Prowspine cusk-eel				238				
Mexican cusk-eel				238				
Velvetnose brotula				6				
Thread brotula								
Oarfish				140				
Splitnose rockfish			47	198	454	47	198	
Mexican rockfish				198			198	
Blackmouth rockfish				333				
Cortez rockfish				333				
Buccaneer rockfish				333				
Atlantic cutlassfish	27,78,200, 216,231,298, 321,412,428		27,78,200, 216,231,298, 321,412,428	27,78,200, 216,231,298, 321,412,428	78		3,78,87,166,167, 183,227,231, 318,412,427	381
Mexican hogfish				418				
Blackspot wrasse				172				
Mangrove wrasse				172				
Wounded wrasse				172				
Chameleon wrasse				172				
Spinster wrasse				172				
Banded wrasse				418				

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5).

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Rock wrasse				140				
Pacific tripletail				188				
Roosterfish				113			113	
Festive drum				76				
Rock croaker				76				
Cape wrasse								
Golden wrasse				172				
California sheephead	198		47	198	66,150,252	251	198	109,209,445
Giant sea bass	47,113		47	113	140,148,150,252	47	113	252
Yellow-brown wrasse				242			242	
Surge wrasse				113			113	
Small reef fish (FMN)								
Sanguine frogfish				371				
Barspot cardinalfish				6				
Flat needlefish	210		210	210			210,427	
Barnaclebill blenny				54				
Notchfin blenny				6				
Purple brotula				151				
Clubhead barnacle blenny				6				
Browncheek blenny				6				
Angel blenny				6				
Zebraface blenny				6				
Plume blenny				6				
Warthead blenny				6				
Scythe butterflyfish				372				
Forcepsfish				320			320	
Threebanded butterflyfish				418				
Barberfish				372				
Coral hawkfish				55			320	
Longnose hawkfish				55				
Giant hawkfish				113			113	
Porcupinefish				42,242	302		42,242	
Balloonfish				42,166,220			42,166,220	
Pacific spadefish				140				
Reef cornetfish				320			320	
Rockwall clingfish				6				
Panamic clingfish				6				
Sonora clingfish				6				
Zebra clingfish				123				
Paradox goby								
Cortez sea chub				54				

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5).

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Topgallant blenny								
Redrump blenny				6				
Largehead moray				297				
Zebra moray				297				
Jewel moray				280				
Palenose moray				267				
Slenderjaw moray				196				
Panamic green moray				267				
Finespotted moray				196				
Masked moray				180				
Argus moray				267				
Hourglass moray				267				
King angelfish				418				
Cortez angelfish				224		174	174	
Panamic sergeant major				180				
Scissortail chromis				180				
Dusky sergeant				180				
Silverstripe chromis				8				
Blue-and-yellow chromis				8				
Bumphead damselfish				8				
Giant damselfish				180				
Whitetail damselfish				375				
Cortez damselfish				8				
Mexican night sergeant				6				
California lizardfish				56				
Bullseye puffer				360		174	360	367
Guineafowl puffer				245				
Spotted sharpnose puffer				60				
Carmine triplefin				6				
Moorish idol				13			227	
Mexican blenny				6				
Scrawled filefish				42			42	
Plain cardinalfish				6				
Tailspot cardinalfish				54				
Pink cardinalfish				6				
Stripebelly puffer				242			242	
Panamic frillfin				418				
Snubnose pipefish				140				
Barred filefish				395			385	
Ocean whitefish			127	198	150,211,252	251	198	252
Pacific burrfish				261				

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5).

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Spikefin blenny				6				
Fantail pipefish				245				
Banded cleaning goby				6				
Readhead goby				6				
Beaubrummel				375				
Clarion damselfish				375				
Sonora goby				6				
Knobchin goby				6				
Sandtop goby				6				
Splitbanded goby				6				
Pacific seahorse				140				
Clarion angelfish				224				
Garibaldi				8	86,15,246,300	251	125	85,87,151, 246,247,335
Barred flagtail				320			320	
Porehead blenny								
Largemouth blenny				418				
Spiny boxfish				423				
Gorgeous goby				6				
Sonora blenny				6				
Halfmoon				140		251	336	151,246,252
Foureye rockskipper				6				
Mexican goatfish				140				
Panamic soldierfish				374				
Gulf brotula				6				
Panamic fanged blenny				180				
Bullseye jawfish				6				
Mexican blenny				54				
Panama spadefish				373				
Sabertooth blenny				6				
Glasseye snapper				42			42	
Popeye catalufa				418				
Secret goby				6				
Peppered moray				297				
Tiger reef eel				297				
Throatspotted blenny				6				
Spotted boxfish				390				
Small demersal fish (FPL)								
Bonefish	87,110,428		87,110,428	87,110,428			87,110,166, 167,242,427	52,87,110,428
Sharpchin slickhead				283				

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5). NCN = no common name.

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Panamic flashlightfish				6				
Roughjaw frogfish				371				
Bandtail frogfish				371				
Flathead sea catfish				208				
Cominate sea catfish				208				
Long-barbeled sea catfish				208				
Chili sea catfish	403		403	403				
Easter Pacific flagfin				415				
Darkedge midshipman	47,96		47	96	47	47	47	47
Saddle midshipman				96	252	251	112	328
Mimetic midshipman				96	252	251	328	328
California needlefish				140				
Keeltail needlefish				97				
Pacific agujon				97				
Houndfish				198			198	
Bay blenny				140				
Mussel blenny				140				
NCN (*Hypsoblennius digueti*)								
East Pacific codlet				123				
Rubynose brotula				222				
Pacific pearlfish				6				
Nocturnal pearlfish				259				
Black snook				113			113	
Blackfin snook				113			113	
White snook				113			113	
Yellowfin snook				58				
Reef-sand blenny				6				
Gulf signal blenny				6				
Elusive signal blenny				6				
Gulf worm blenny				6				
Cortez pikeblenny								
Barcheek blenny								
Whitesaddle stargazer				6				
Halfbanded stargazer				6				
Giant stargazer				180				
Notchtail stargazer				123				
Ornate stargazer				123				
Longjaw stargazer								
Spotfin burrfish				239				
Pink seaperch				140				
Deepwater cornetfish				161				

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5). NCN = no common name.

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Slender clingfish				140				
Southern clingfish				140				
Rosy clingfish				6				
Cortez clingfish				6				
Tadpole clingfish				6				
Smoothlip clingfish								
Blackstripe clingfish								
Guadalupe clingfish								
Slow goby				6				
Saddlebanded goby								
Panther goby				6				
Tailspot goby								
Frailscale goby								
NCN (*Bollmannia longipinnis*)								
Pennant goby								
NCN (*B. pawneea*)								
Enigmatic goby								
Shortjaw mudsucker								
Widebanded cleaning goby								
Bright goby								
Lingcod	203,386	203	203,386	203,386	252	252	113	203
Painted greenling				89				
Shortspine combfish	149		149	149				
Tinsel squirrelfish				374				
Sargassum blenny				6				
Longjaw blenny				6				
Phallic blenny				6				
Hidden blenny								
Baja blenny								
Pink blenny								
Fugative blenny								
Broadfin snailfish				402				
NCN (*Psednos pallidus*)				79				
NCN (*P. griseus*)								
Shoulderspot grenadier				92				
NCN (*Neoconger vermiformis*)								
California moray				140	302	251	336	
Hardtail moray				267				
Spottail moray				267				
White-edged moray				267				
NCN (*Gymnothorax eurygnathos*)								

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5). NCN = no common name.

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Shorthead hagfish				145				
Cortez hagfish				145				
Palebelly searsid				337				
NCN (*Mentodus eubranchus*)				263				
Iguana lizardfish				360			360	
Oceanic puffer				113			113	
Peruvian puffer				360			360	
Naked puffer				105				
NCN (*Lycenchelys folletti*)				14				
Cortez triplefisn				6				
Apostrophe goby								
Pacific porgy				140				
Enigmatic tilefish				130				
Orangethroat pikeblenny				140				
Rubble goby				6				
Gecko goby				6				
Redlight goby				6				
Lizard triplefin				6				
Longtail goby				140				
Moonstruck stargazer								
Silt goby								
Longjaw mudsucker				140	252,442	442		252
Gulf opaleye				54				
Bearded clingfish				140				
Crescent goby				6				
Smooth stargazer	149		149	149			149	47
Blue-bronze chub				140				
Green blenny				6				
Bluebanded goby				140				
Fishgod goby				6				
Redside goby				6				
Margarita goby				6				
Zaca goby				6				
Glossy goby				6				
Roundscale goby				6				
Dart stargazer								
Finespotted jawfish				113			113	
Giant jawfish				6				
Flapscale blenny				6				
Northern fraildisc clingfish								
Shadow goby				140				

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5).

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Bluestriped chub				157				
Longnose puffer				360			360	
Pinstriped blenny								
Hose blenny								
Lance lizardfish				56			2	
Pacific angel shark (FPS)								
Pacific angel shark	36,64		64	64	64	252		165
Small migratory sharks (FPO)								
Sharptooth smoothhound				99				
Brown smoothhound	65		65	65	461	460		461
Sicklefin smoothhound				101				
Gray smoothhound	65		65	65	461	47	47	461
Large pelagic sharks (FVB)								
Bigeye thresher shark	244		244	244			87,221,244	315
Blacktip shark	87,213		87,213	87,213	101		87,167,427	101,120,393
Smalltail shark	241		241	241				241
Nurse shark	193		193	193	302		42,87	
Pelagic thresher shark	249		249	249			249	47
Thresher shark	87	47	87	87	252	252	221	47
Bull shark	48,192,456		48,192,456	48,192,456	456		43,90,167,427	164
Dusky shark	192,299,382		192,299,382	192,299,382	209		43,221,427	164
White shark	455		455	455	393	252	91,221,285, 344,427	455
Shortfin mako shark	87,335	47	87,335	87,335	335	252	87,221	87,335
Pacific sharpnose shark				101		277		277
Scalloped hammerhead shark	49,77,87,192		49,77,87,192	49,77,87,192	393		49,77,221, 242,406	164
Great hammerhead shark				167,406			167,406	
Smooth hammerhead shark				296			427	
Guitarfish (FVD)	**288**							
Thornback				140				
Banded guitarfish				140				
Whitesnout guitarfish				273				
Speckled guitarfish				273				
Shovelnose guitarfish			47	113	47	47	113	358
Skates, rays, sharks (FVO)								
Spotted ratfish	321		321	321				
Whiptail stingray				198			198	
California butterfly ray				270		352	352	
Longsnout butterfly ray				270				
Horn shark				100		63		

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5).

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Mexican horn shark				100				
Spotted eagle ray				234			427	234
Bat ray	260		260	260				
Smoothtail mobula				140				
Giant electric ray				271				
Bullseye electric ray				271				
Longnose cat shark				101				
Swell shark				101		47		
Leopard shark	230,391		230	230	101,230	47	392	230
Round stingray	321		321	321			113	
Blotched stingray				274				
Reef stingray				274				
Cortez stingray				274				
Thorn stingray				274				
Diamond stingray				140				258
Longnose eagle ray				269				
Equatorial skate				272				
Golden cownose				180				
Flatfish (FVS)								
Pacific lined sole	444		444	444			444	
Network sole				226				
Spotted fin sole				226				
Pacific eyed flounder				411				
Pacific leopard flounder				190				
Pacific flag flounder				190				
California tonguefish				140				
Halfspotted tonguefish				293				
Chocolate tonguefish				293				
Darkcheek tonguefish				293				
Banded tonguefish				293				
Dwarf tonguefish				293				
Blacktail tonguefish				293				
Drab tonguefish				293				
Whitetail tonguefish				293				
Halfstriped tonguefish				293				
Yellow tonguefish				293				
Elongate tonguefish				293				
Cortez halibut				19				
Five-rayed sanddab				141				
Three spot sand flounder				74				
Gulf sanddab				191				

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5). NCN = no common name.

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Speckled sanddab				140	47,252	47,251,252,339	47,155	
Longfin sanddab				140				
Fringed flounder	347		347	347	346		346	347
Spotted flounder								
Bigmouth sole				140				
California halibut	255,345		255	255	223,252	251,252	198	137
Dappled flounder				54				
Ocellated turbot				397				
Hornyhead turbot				140		47,251,252		
Oval flounder				191			47	
Fantail sole				198			198	
Mojarra (FVT)								
Yellowfin mojarra	87,434		87,434	87,434		174	42,87,167	
Peruvian mojarra	444			444		174	444	
Black axillary mojarra			47	59				
Pacific flagfin mojarra				360		174	360	
Darkspot mojarra				59		174	174	
Golden mojarra				59				
Scorpionfish (FVV)								
Speckled scorpianfish				360			360	
Sonora scorpionfish				333				
Splitnose searobin				61				
Lumptail searobin	278,370		278,370	278,370			278,360,370	278,370
Chevron searobin				61				
Whitesnout searobin	370		370	370			370	
Twobeak searobin				61				
Rough searobin				360			360	
California scorpionfish	139,321		139,321	139,321	252,253	251	253	252,253
Player scorpionfish				333				
Stone scorpionfish				418				
Spotted scorpionfish				42,87,133			42,87,133	
Reddish scorpionfish				360			360	
Rainbow scorpionfish				140				
Lanternfish and deep (SHB)								
Mexican lampfish				140				
Lampfish				140				
Slimtail lampfish								
Rounded batfish	149		149	149				
NCN (*Dibranchus hystrix*)				46				
NCN (*D. spinosus*)				46				
Pacific viperfish	149		149	149	20		305	

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5).

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Black-belly dragonfish	149		149	149				
Scaleless dragonfish								
Totoaba (SHC)								
Totoaba	82	82	40,321	40,82,321	40	76,152	11	82
Large pelagics (SHD)								
Pilotfish	349			349	302		349	
Green jack				198			198	
Pacific crevalle jack				113			113	
Threadfin jack				250				
Bigeye trevally	292		292	292			185,377,435	
Cocinero				6				
Pacific bumper				394				
Shortfin scad	16,23,44, 104,135,200, 202,235,309, 327,361,399, 400,409		16,23,44, 104,135,200, 202,235,309, 327,361,399, 400,409	16,23,44,104,135, 200,202,235, 309,327,361, 399,400,409			23,309, 318,359,399	
Yellowfin jack				394				
Blackfin jack				394				
Blackblotch pompano				394				
Paloma pompano				140				
Gafftopsail pompano				198			198	
Golden trevally	104,136		104,136	104,136			136,242,377	
Dolphinfish	4,233,308, 316,428,431		4,233,308, 316,428,431	4,233,308, 316,428,431	160		4,233,308, 312,430,435	35,214, 307,308
Remora				198			198	
Machete				169				
Opah				113,149			113,149	
Ocean sunfish	334		334	334			108	
Slender mola				88				
Charcoal codling				317				
Whale shark	324,457		324,457	324,457			156	98,180, 324,457
Chinook salmon				113	195,302		113	132
Skipjack tuna	80,87,135, 139,184,200, 206,212,321, 323,329,332, 383,410		80,87,135, 139,184,200, 206,212,321, 323,329,332, 383,410	80,87,135, 139,184,200, 206,212,321, 323,329,332, 383,410	93		87,281,427,435	264
Bullet mackerel				94				
Frigate mackerel				94				
Cortez barracuda				398				

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5).

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Cortez butterfish				182				
Salema butterfish				182		251		163
Swordfish	5,67,87, 321,364,405, 408		5,67,87, 321,364,405, 408	5,67,87,321,364, 405,408			5,67,87,167,243	286
Black skipjack				93			291	
Longjaw leatherjack				113			113	
Pacific bonito	319,459		319,459	319,459			103,319	47
Yellowtail jack	170,170,321		321	170,321	47	47	29,427,435	209
Almaco jack				42,310	30,252,407	251	42,310	
Mexican barracuda	113,331		251	113	10,151,407,441	251	113	10,186,217, 407,441
Rainbow runner	200		200	200			227	
Mackerel (SHP)								
Jack mackerel	240,321		240,321	240,321	147		240	186
Snake mackerel				149			149	
Gulf sierra	95,163		163	95		254	201	433
Pacific chub mackerel	40,73,81, 117,129,139, 219,229,279, 314,321,326, 435		40,73,81, 117,129,139, 219,229, 279,314,321, 326,435	40,73,81, 117,129,139, 219,229,279, 314,321,326, 435	72	47	103,117,129,131, 173,183,219, 256,326,404, 435	164
Pacific sierra			276	113		198	113	163
Hake (SHR)								
Panama hake	321,323		321,323	321,323		26,70	26,70	26,70
Cortez hake								
Small pelagics (SSK)								
Pacific argentine	149		149	149	149		149	
Topsmelt				236	186		83	236
False grunion					84	251	83	124
Longfin silverside				6	84	251	83	124
Pitcher silverside				236	83		83	162
Delta silverside				236	83		83	162
Gulf grunion				236	178,252,401	251	83,378	83
California smoothtongue				140		47		

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5).

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Pacific sardine	25,40,41, 68,81,122, 139,154,176, 194,301,321, 322,323,414, 424,428,432, 440		25,40,41, 68,81,122, 139,154,176, 194,301,321, 322,323,414, 424,428,432, 440	25,40,41, 68,81,122, 139,154,176, 194,301,321, 322,323, 414,424,428, 432,440	452	47	39,185,301, 425,427	17,153,159
Flatiron herring				449				
Deepbody thread herring	69,81		69,81	69,81			69	
Striped herring	444		444	444	47	47	444	
Yellowfin herring				448				
Dove's longfin herring				448				
Short anchovy	181,451		47	451	47	47	47	47
Persistent anchovy				451				
Bigscale anchovy				447			47	
Anchoveta	31,32,33,34,321		31,32,33,34,321	31,32,33,34,321	34			34
Northern Gulf anchovy				451		174	174	
False Panama anchovy	311		311	311			311	
Sharpnose anchovy				447		174	174	
Slender anchovy				451				
Bignose anchovy	33,207		33,207	33,207				
Silverstripe anchovy				451				
Gulf anchovy				451				
California flyingfish				313				
Beautyfin flyingfish				313				
Mysticeti (WHB)								
Bryde's whale			304					
Fin whale			366	429	429	429	429	325
Blue whale				429	429	429	429	325
Gray whale			351	351	429	429	429	325
Humpback whale	284			429	429	429	429	325
Odontocetae (WHT)								
Long-beaked common dolphin				429	325	429	429	325
Common dolphin				429	325	429	429	325
Bottlenose dolphin				429	429	429	429	325
Pacific white-sided dolphin				146	146	429	429	325
Baird's beaked whale				429	429	429	429	325
Sperm whale	142		142	429	429	429	429	325
Short-finned pilot whale				429	429	429	429	325
False killer whale								
Pygmy beaked whale								

Table A-4 continued. Life history parameter references (numbers keyed to Table A-5).

Name	M	F	k	L∞	Tmax (years)	Lmax (cm)	a/b	Mature (years)
Orca (WHS)								
Orca, aka killer whale	295		303	429	429	429	429	325
Vaquita (WDG)								
Vaquita		119	62		458	51	429	356
Pinnipeds (PIN)								
Elephant seal	47		47	429	325	429	429	
California sea lion		47		429	429	429	429	325
Oceanic sea turtles (SP)								
Leatherback turtle	75		62	179		179		348,464
Olive Ridley turtle						179		
Reef associated turtles (REP)								
Loggerhead turtle			218	218		218		218
Hawksbill turtle								
Green turtle	289		45,158	45,158		158		158
Sea birds (SB)								
Blue-footed booby								
Brown booby								
Heermann’s gull								
California gull	376				376			376
Yellow-footed gull								
Elegant tern								
Royal tern								
Forster’s tern								
Black storm-petral	47				376			376
Least storm-petral								
Brandt’s cormorant	205				376			376
Double-crested cormorant								
Magnificent frigatebird			306	306				
American oystercatcher								
Snowy egret								
Reddish egret								
Great egret								
Great blue heron								
Whimbrel								
Least sandpiper								
Black turnstone								
Brown pelican	47				376			376
Sooty shearwater	47		47		376			376
Flesh-footed shearwater								
Eared grebe								
Craveri’s murrelet								

Table A-5. List of references consulted for life history parameters in Table A-4.

ID No.	Source
1	Aburto-Oropeza, O., E. Ezcurra, G. Danemann, V. Valdez, J. Murray, and E. Sala. 2008. Mangroves in the Gulf of California increase fishery yields. Proc. Natl. Acad. Sci. USA 105:10456–10459.
2	Aguirre, H., F. Amezcua, J. Madrid-Vera, and C. Soto. 2008. Length–weight relationship for 21 fish species from a coastal lagoon in the southwestern Gulf of California. J. Appl. Ichthyol. 24:91–92.
3	Al Sakaff, H., and M. Esseen. 1999. Length-weight relationship of fishes from Yemen waters (Gulf of Aden and Red Sea). Naga ICLARM Q. 22(1):41–42.
4	Alfaro, G. M. T. 1996. Edad y crecimiento de *Coryphaena hippurus* (Linnaeus 1758) (Osteichthyes: Coryphaenidae), en el Sur de la península de Baja California, Mexico. Master's thesis. Instituto Politecnico Nacional, CICIMAR, Mexico.
5	Aliçli, T. Z., and I. K. Oray. 2001. Age and growth of swordfish (*Xiphias gladius* L., 1758) in the eastern Mediterranean Sea. Col. Vol. Sci. Pap. ICCAT 52:698–707.
6	Allen, G. R., and D. R. Robertson. 1994. Fishes of the tropical eastern Pacific. University of Hawaii Press, Honolulu.
7	Allen, G. R. 1985. Snappers of the world: An annotated and illustrated catalogue of lutjanid species known to date. Food and Agriculture Organization species catalogue, vol. 6. FAO Fish. Synop. 6(125), FAO, Rome.
8	Allen, G. R. 1991. Damselfishes of the world. Mergus Publishers, Melle, Germany.
9	Allen, L. G. 1985. A habitat analysis of the nearshore marine fishes from southern California. Bulletin of the Southern California Academy of Sciences 84(3):133–155.
10	Ally, J. R. R., and K. Miller. 1992. California barracuda. *In* W. S. Leet, C. M. Dewees, and C. W. Haugen (eds.), California's living marine resources and their utilization, p. 157–160. California Sea Grant Extension Publication UCSGEP-92-12. California Sea Grant Extension Program, Univ. California Davis, Dept. Wildlife and Fisheries Biology.
11	Almeida-Paz, M., G. Morales-Abril, and M. J. Roman-Rodriguez. 1992. Aspectos sobre aclimatacion y crecimiento de juveniles de totoaba, *Totaba macdonaldi* (Gilbert) (Pices: Sciaenidae) en condicions de cautiverio. Ecologica 2:7–12.
12	Alvarez Tinarejo, M. D. C. 1997. Analisis microscopico gonadal y fecundidad del chano, *Micropogonias megalops*, en el litoral del alto Golfo de California, para el perido 1993–1995. Universidad Autónoma de Baja California, Ensenada, BC, Mexico.
13	Anderson, C., and A. Hafiz. 1987. Common reef fishes of the Maldives. Novelty Press, Republic of Maldives.
14	Anderson, M. E. 1995. The eelpout genera *Lycenchelys* Gill and *Taranetzella* Andriashev (Teleostei: Zoarcidae) in the eastern Pacific, with descriptions of nine new species. Proc. Calif. Acad. Sci. 49(2):55–113.
15	Annala, J. H. (ed.). 1994. Report from the Fishery Assessment Plenary, May 1994: Stock assessments and yield estimates. Unpublished report held in MAF Fisheries Greta Point library, Wellington, New Zealand.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
16	FAO (U.N. Food and Agriculture Organization). 1985. Report of the Second Working Group Meeting on the Mackerels (*Decapterus* and *Rastrelliger* spp.) in the Malacca Strait, 4–9 October 1985, Colombo, Sri Lanka. Bay of Bengal Programme Document.
17	Fisheries Agency of Japan. 2001. Increasing competition between fisheries and whales. Japan's whale research in the western north Pacific (JARPN II). Fisheries Agency, Government of Japan, Tokyo.
18	Appeldoorn, R. S., G. D. Dennis, and O. M. Lopez. 1987. Review of shared demersal resources of Puerto Rico and the Lesser Antilles region. U.N. Food and Agriculture Organization Fish. Rep. 383:36–104, FAO, Rome.
19	Arellano-Martinez, M., and J. De La Cruz-Agüero. 1997. New records and range extensions of fishes on the Pacific coast of Mexico. Rev. Biol. Trop. 45(2):936.
20	Armstrong, R. H. 1996. Alaska's fish. A guide to selected species. Alaska Northwest Books, Portland, OR.
21	Arnoldi, D. C., W. H. Herke, and E. J. Clairain Jr. 1973. Estimate of growth rate and length of stay in a marsh nursery of juvenile Atlantic croaker, *Micropogonias undulatus* (Linnaeus), sandblasted with florescent pigments. Proceedings of the Gulf and Carribean Fisheries Institute 26:158–172. Gulf and Carribean Fisheries Institute, Marathon, FL.
22	Arreguín-Sánchez, F., L. Beléndez-Moreno, I. M. Gómez-Humarán, R. Solana Sansores, and C. Rangel Dávalos. 2006. Sustentabilidad y pesca responsable en Mexico. *In* I. N. d. l. Pesca (ed.), Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca Y Alimentacion.
23	Atmadja, S. B. 1988. Estimation of growth and mortality of round scad (*Decapterus macrosoma*) in the Java Sea, Indonesia. U.S. Food and Agriculture Organization Fish. Rep. 389:324–345. FAO, Rome.
24	Avilés Quevedo, A. e. a. 1995. Biología y cultivo de la cabrilla arenera *Paralabrax maculatofasciatus* (Steindachner 1868). Centro Regional de Investigación Pesquera la Paz., La Paz, BCS, Mexico.
25	Baird, D. 1970. Age and growth of the south African pilchard, *Sardinops ocellata*. Invest. Rep. Div. Sea Fish. S. Afr. No. 91:1–16.
26	Balart-Páez, E. F. 2005. Biología y ecología de la merluza baja Californiana, *Merluccius angustimanus* Garman, 1899, en la costa occidental de Baja California Sur, Mexico. Doctoral dissertation. Universidad Autónoma de Nuevo León, Monterey, NL.
27	Banerji, S. K., and T. S. Krishnan. 1973. Acceleration of assessment of fish populations and comparative studies of similar taxonomic groups. *In* Proceedings of the Symposium on Living Resources of the Seas Around India, p. 158–175. CMFRI special publication, Cochin, India.
28	Barroso-Soto, I., E. Castillo-Gallardo, C. Quiñonez-Velazquez, and R.E. Morán-Angulo. 2007. Age and growth of the finescale triggerfish, *Balistes polylepis* (Teleostei: Balistidae), on the Coast of Mazatlán, Sinaloa, Mexico. Pac. Sci. 61(1):121–127.
29	Baxter, J. 1960. A study of the yellowtail *Seriola dorsalis* (Gill). California Fish Game Fish. Bull. 110:1–91.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
30	Baxter, J. L., and R. D. Collyer. 1960. Results of tagging experiments. *In* J. L. Baxter (ed.), A study of the yellowtail *Seriola dorsalis* (Gill). California Dept. Fish and Game, Fish Bull. 110:52–77.
31	Bayliff, W. H. 1963. Observations on the life history and identity of intraspecific groups of the anchoveta, *Cetengraulis mysticetus*, in Montijo Bay and Chiriqui Provence, Panama. Bull. I-ATTC 8:167–197.
32	Bayliff, W. H. 1966. Population dynamics of the anchoveta, *Cetengraulis mysticetus*, in the Gulf of Panama as determined by tagging experiments. Bull. I-ATTC 11:173–352.
33	Bayliff, W. H. 1967. Growth, mortality, and exploitation of the Engraulidae, with special reference to the anchoveta, *Cetengraulis mysticetus*, and the Colorado, *Anchoa naso*, in the eastern Pacific Ocean. Bull. I-ATTC 12:365–432.
34	Bayliff, W. H. 1969. Synopsis of biological data on the anchoveta *Cetengraulis mysticetus* Günther, 1866. U.N. Food and Agriculture Organization Spec. Synop. 43. FAO, Rome.
35	Beardsley, G. L. 1967. Age, growth, and reproduction of the dolphin, *Coryphaena hippurus*, in the Straits of Florida. Copeia 1967(2):441–451.
36	Bedford, D. W. 1987. Pacific angel shark management information document. Pangas PDF Database. (Available from A. Cinti, University of Arizona, School of Natural Resources, Biological Sciences East, Room 104, Tucson, AZ 85721.)
37	Bellwood, D. R. 1995. Scaridae. Loros, pocochos. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, Pacifico Centro-Oriental, p. 1419–1426. FAO, Rome.
38	Benno, B. L. 1992. Some features of beach seine fishery along the Dar es Salaam coast, Tanzania. Master's thesis. Univ. Kuopio (Eastern Finland), Dept. Applied Zoology, Kuopio, Finland.
39	Berg, L., L. S. Bogdanov, N. I. Kozhin, and T. S. Rass (eds.). 1949. Commercial fishes of the USSR. Pshchepromizdat.
40	Beverton, R. J. H., and S. J. Holt. 1959. A review of the lifespans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. *In* G. E. W. Wolstenholme and M. O'Connor (eds.), CIBA Foundation colloquia on ageing: The lifespan of animals, vol 5., p. 142–180. J & A Churchill Ltd., London.
41	Beverton, R. J. H. 1963. Maturation, growth, and mortality of clupeid and engraulid stocks in relation to fishing. Cons. Perm. Int. Explor. Mer, Rapp. p.-v. Réun. 154:44–67.
42	Bohnsack, J. A., and D. E. Harper. 1988. Length-weight relationships of selected marine reef fishes from the southeastern United States and the Caribbean. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-SEFSC-215.
43	Bonfil, R. S., D. F. de Anda, and R. A. Mena. 1990. Shark fisheries in Mexico: The case of Yucatan as an example. U.S. Dept. Commer., NOAA Tech. Rep. NMFS 90:427–441.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
44	Boonraksa, V. 1987. Preliminary resource analysis of chub mackerel (*Rastrelliger* spp.) and round scads (*Decapterus* spp.) in the west coast of Thailand. Paper presented at Third Working Group Meeting of the Malacca Strait Project/BOBP, 18–26 August 1986, Phuket, Thailand.
45	Boulon, R. H., and N. B. Frazer. 1990. Growth of wild juvenile caribbean green turtles, *Chelonia mydas.* J. Herpetol. 24:441–445.
46	Bradbury, M. G. 1999. A review of the fish genus *Dibranchus* with descriptions of new species and a new genus, *Solocisquama*. Proc. Calif. Acad. Sci. 51(5):259–310.
47	Brand, E. J., I. C. Kaplan, C. J. Harvey, P. S. Levin, E. A. Fulton, A. J. Hermann, and J. C. Field. 2007. A spatially explicit ecosystem model of the California Current's food web and oceanography. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-84.
48	Branstetter, S., and R. Stiles. 1987. Age and growth of the bull shark, *Carcharhinus leucas*, from the northern Gulf of Mexico. Environ. Biol. Fish. 20:169–181.
49	Branstetter, S. 1987. Age, growth, and reproductive biology of the silky shark, *Carcharhinus falciformis*, and the scalloped hammerhead, *Sphyrna lewini*, from the northwestern Gulf of Mexico. Environ. Biol. Fish. 19:161–173.
50	Brothers, E. B., and R. E. Thresher. 1985. Pelagic duration, dispersal, and the distribution of Indo-Pacific coral-reef fishes. Symp. Ser. Undersea Res. 3:53–69.
51	Brownell, R. L., L. T. Findley, O. Vidal, A. Robles, and S. N. Manzanilla. 1987. External morphology and pigmentation of the vaquita *Phocoena sinus* (cetacea: Mammalia). Mar. Mammal Sci. 3:22–30.
52	Bruger, G. E. 1974. Age, growth, food habits, and reproduction of bonefish, *Albula vulpes*, in south Florida waters. Fla. Mar. Res. Pub. 3:1–20.
53	Bullock, L. H., M. D. Murphy, M. F. Godcharles, and M. E. Mitchell. 1992. Age, growth, and reproduction of jewfish *Epinephelus itajara* in the eastern Gulf of Mexico. Fish. Bull. 90:243–249.
54	Burgess, W. E., H. R. Axelrod, and R. E. Hunziker III. 1990. Dr. Burgess' Atlas der Meerwasser Aquarium Fische. Bede Verlag, Kollenburg, Germany.
55	Bussing, W. A., and R. J. Lavenberg. 1995. Cirrhitidae. Chinos, halcones. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca. Pacifico Centro-Oriental, p. 1007–1010. 3 vols. FAO, Rome.
56	Bussing, W. A., and R. J. Lavenberg. 1995. Synodontidae. Lagartos. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca. Pacifico Centro-Oriental, p. 1625–1628. 3 vols. FAO, Rome.
57	Bussing, W. A. 1995. Balistidae. Pejepuercos, calafates, gatillos. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca. Pacifico Centro-Oriental, p. 905–909. 3 vols. FAO, Rome.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
58	Bussing, W. A. 1995. Centropomidae. Róbalos. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca. Pacifico Centro-Oriental, p. 987–995. 3 vols. FAO, Rome.
59	Bussing, W. A. 1995. Gerreidae. Mojarras. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca. Pacifico Centro-Oriental, p. 1114–1128. 3 vols. FAO, Rome.
60	Bussing, W. A. 1995. Tetraodontidae. Tamboriles, tamborines, botetes, peces globo, corrotuchos. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca. Pacifico Centro-Oriental, p. 1629–1637. 3 vols. FAO, Rome.
61	Bussing, W. A. 1995. Triglidae. Rubios. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca. Pacifico Centro-Oriental, p. 1643–1648. 3 vols. FAO, Rome.
62	Ainsworth, C. Assumption.
63	Cailliet, G. M., E. J. Burton, J. M. Cope, L. A. Kerr, R. J. Larson, R. N. Lea, D. VenTresca, and E. Knaggs. 2000. Biological characteristics of nearshore fishes of California: A review of existing knowledge and proposed additional studies. Pacific Fishery Management Council, Portland, OR.
64	Cailliet, G. M., H. F. Mollet, G. G. Pittenger, D. Bedford, and L. J. Natanson. 1992. Growth and demography of the Pacific angel shark (*Squatina californica*) based upon tag returns off California. Aust. J. Mar. Freshw. Res. 43:1313–1330.
65	Cailliet, G. M., K. G. Yudin, S. Tanaka, and T. Taniuchi. 1990. *In* Growth characteristics of two populations of *Mustelus manazo* from Japan based upon cross-readings of vertebral bands, p. 167–176. U.S. Dept. Commer., NOAA Tech. Rep. NMFS 90.
66	CDFG (California Dept. Fish and Game). 1982. California Fish and Wildlife Plan. Vol. II Species plans, Part C-living marine resources. Preliminary draft, June 1982. (Available from California Dept. Fish and Game, 1416 Ninth Street, Sacramento, CA 95814.)
67	Campillo, A. 1992. Les pêcheries françaises de Méditeranée: Synthèse des connaissances. Institut Francais de Recherche pour l'Exploitation de la Mer, France.
68	Cárdenas, G., and J. Mendo. 1985. Preliminary length-based growth parameter estimates of Peruvian sardine (*Sardinops sagax sagax*). Fishbyte 3(3):10–12.
69	Carmona, R., and F. Alexandres. 1994. Determinación del crecimiento de opisthonema libertate (Clupeiformes: Clupeidae) mediante lectura de otolitos. Rev. Biol. Trop. 42(1/2):233–238.
70	Casas-Valdez, M., and G. Ponce-Díaz (eds.). 1996. Estudio del potencial pesquero y acuícola de Baja California Sur. Vol 1. SEMARNAP-Gobierno del Estado de B.C.S.-FAO-INP-UABCS-CIB-CICIMAR-CETMAR. Mexico.
71	Castro Gonzalez, J. J. 2004. Estudio base y estrategias de manejo de la pesqueria del chano *Micropogonias megalops*, caso de estudio: Alto Golfo de California. Universidad Autónoma de Baja California, Ensenada.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
72	Castro Hernández, J. J., and A. T. Santana Ortega. 2000. Synopsis of biological data on the chub mackerel (*Scomber japonicus* Houttuyn, 1782). FAO Fish. Synop. 157. FAO, Rome.
73	CECAF (Committee for the Eastern Central Atlantic Fisheries). 1979. Report of the ad hoc working group on west African coastal pelagic fish from Mauritania to Liberia (26°N to 5°N). CECAF/ECAF Ser. 78/10. FAO, Rome.
74	CENAIM (Centro Nacional de Acuicultura e Investigaciones Marinas). 1992. A field guide to the edible fishes and shellfishes in coastal waters of Ecuador. Centro Nacional de Acuicultura e Investigaciones Marinas, Ecuador.
75	Chaloupka, M. Y., and C. J. Limpus. 2002. Survival probability estimates for the endangered loggerhead sea turtle resident in southern Great Barrier Reef waters. Mar. Biol. 140:267–277.
76	Chao, L. N. 1995. Sciaenidae. Corvinas, barbiches, bombaches, corvinatas, corvinetas, corvinillas, lambes, pescadillas, roncachos, verrugatos. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identificacion de especies para los fines de la pesca. Pacifico Centro-oriental, p. 1427–1518. 3 vol. FAO, Rome.
77	Chen, C. T., T. C. Leu, S. J. Joung, and N. C. H. Lo. 1990. Age and growth of the scalloped hammerhead, *Sphyrna lewini*, in northeastern Taiwan waters. Pac. Sci. 44:156–170.
78	Chen, W. Y., and S. C. Lee. 1982. Age and growth of the ribbonfishes *Trichiurus* (Perciformes: Trichiuridae) of Taiwan. Bull. Inst. Zool., Acad. Sin. 21:9–20.
79	Chernova, N. V., and D. L. Stein. 2002. Ten new species of *Psednos* (Pisces, Scorpaeniformes: Liparidae) from the Pacific and North Atlantic oceans. Copeia 2002(3):755–778.
80	Chur, V. N., and V. L. Zharov. 1983. Determination of age and growth rate of the skipjack tuna, *Katsuwonus pelamis* (Scombridae), from the southeastern part of the Gulf of Guinea. J. Ichthyol. 23(3):53–67.
81	Cisneros, M. A., J. Estrada, and G. Montemayor. 1990. Growth, mortality, and recruitment of exploited small pelagic fishes in the Gulf of California, Mexico. Fishbyte 8(1):15–17.
82	Cisneros-Mata, M. A., G. Montemayor-López, and M. J. Román-Rodríguez. 1995. Life history and conservation of *Totaba macdonaldi*. Conserv. Biol. 9:806–814.
83	Clark, F. N. 1925. The life history of *Leuresthes tenuis*, an atherine fish with tide controlled spawning habits. Calif. Dept. Fish Game Fish Bull. 10.
84	Clark, F. N. 1929. The life history of the California jack smelt, *Atherinopsis californiensis*. Calif. Dept. Fish Game Fish Bull. 16:5–22.
85	Clarke, T. A. 1970. Territorial behavior and population dynamics of a pomacentrid fish, the garbaldi, *Hypsypops rubicunda*. Ecol. Monogr. 40(2):189–212.
86	Clarke, T. A. 1971. Territoriality boundaries, courtship, and social behavior in the garabaldi, *Hypsypops rubicunda* (Pomacentridae). Copeia 1971(2):295–299.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
87	Claro, R., and J. P. García-Arteaga. 1994. Crecimiento. *In* R. Claro (ed.), Ecología de los peces marinos de Cuba, p. 321–402. Instituto de Oceanologia Academia de Ciencias de Cuba and Centro de Investigaciones de Quintana Roo (CIQRO), Mexico.
88	Claro, R. 1994. Características generales de la ictiofauna. *In* R. Claro (ed.), Ecología de los peces marinos de Cuba, p. 55–70. Instituto de Oceanología Academia de Ciencias de Cuba and Centro de Investigaciones de Quintana Roo (CIQRO), Mexico.
89	Clemens, W. A., and G. V. Wilby. 1961. Fishes of the Pacific coast of Canada. 2nd edition. Fish. Res. Bd. Canada Bull. (68):443.
90	Cliff, G., and S. F. J. Dudley. 1991. Sharks caught in the protective gill nets off Natal, South Africa. The bull shark *Carcharinus leucas* Valenciennes. S. Afr. J. Mar. Sci. 10:253–270.
91	Cliff, G., S. F. J. Dudley, and M. R. Jury. 1996. Catches of white sharks in KwaZulu-Natal, South Africa, and environmental influences. *In* A. P. Klimley and D. G. Ainley (eds.), Great white sharks: The biology of *Carcharodon carcharias*., p. 351–362. Academic Press Inc., San Diego.
92	Cohen, D. M., T. Inada, T. Iwamoto, and N. Scialabba. 1990. U.N. Fish and Agriculture Organization species catalogue. Vol. 10. Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers, and other gadiform fishes known to date. FAO Fish. Synop. 10 (125). FAO, Rome.
93	Collette, B. B., and C. E. Nauen. 1983. U.N. Fish and Agriculture Organization species catalogue. Vol. 2. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos, and related species known to date. FAO Fish. Synop. 2(125). FAO, Rome.
94	Collette, B. B., and C. R. Aadland. 1996. Revision of the frigate tunas (Scombridae, Auxis), with descriptions of two new subspecies from the eastern Pacific. Fish. Bull. 94:423–441.
95	Collette, B. B., and J. L. Russo. 1979. An introduction to the spanish mackerels, genus *Scomberomorus*. *In* E. L. Nakumua and H. R. Bullis (eds.), Proceedings of the Mackerel Colloqium, p. 3–16. Gulf States Marine Fisheries Commission, Ocean Springs, MS.
96	Collette, B. B. 1995. Batrachoididae. Peje-sapos, sapos. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 910–918. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
97	Collette, B. B. 1995. Belonidae. Agujones, maraos. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 919–926. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
98	Colman, J. G. 1997. A review of the biology and ecology of the whale shark. J. Fish Biol. 51(6):1219–1234.
99	Compagno, L. J. V., F. Krupp, and W. Schneider. 1995. Tiburones. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para los fines de la pesca, p. 647–744. Pacifico Centro-Oriental. 3 vols. FAO, Rome.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
100	Compagno, L. J. V. 1984. U.N. Food and Agriculture Organization species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 1. Hexanchiformes to Lamniformes. FAO Fish. Synop. 125, Vol. 4, Part 1. FAO, Rome.
101	Compagno, L. J. V. 1984. U.N. Food and Agriculture Organization species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2. Carcharhiniformes. FAO Fish. Synop. 125, Vol. 4, Part 2. FAO, Rome.
102	Cordes J. F. 1992. Age, growth, spawning periodicity, settlement, and distribution of the young-of-the-year and older juvenile kelp bass (*Paralabrax clathratus*) in the southern California Bight during 1988–1990. Master's thesis. California State Univ., Northridge.
103	Corporacion de Fomento de la Produccion (Chile). 1980. Catálogo de recursos pesqueros Chile. Instituto de Fomento Pesquero, Gerencia de Desarollo, CORFO, Santiago, Chile.
104	Corpuz, A., J. Saeger, and V. Sambilay. 1985. Population parameters of commercially important fishes in Philippine waters. Tech. Rep. 6:1–99. Univ. Philippines, Dept. Marine Fisheries, Quezon City, Philippines.
105	Cota-Gómez, V. M., J. De La Cruz-Agüero, and M. A. Martínez. 1998. Distributional notes on some marine fishes collected on southern Baja California, Mexico. Biol. Invest. Mar. Cost. 27:103–105.
106	Cotto-Sanchéz, A. 1998. Listado taxonómico de los pesces identificados en los océanos Pacífico y Atlántico de Nicaragua. Ministerio de Economia y Desarrollo, MEDE PESCA, Managua, Nicaragua.
107	Cotto, A. 1998. La pesca del pargo en Nicaragua. *In* J.E. Arellano (ed.), Peces y pesca en los mares y lagos de Nicaragua, p. 35–36. Boletin Nicaraguense de Bibliografia y Documentation, No. 102.
108	Coull, K. A., A. S. Jermyn, A. W. Newton, G. I. Henderson, and W. B. Hall. 1989. Length/weight relationships for 88 species of fish encountered in the North Atlantic. Scottish Fish. Res. Rep. 43.
109	Cowen, R. K. 1990. Sex changes and life history patterns of the Labrid, *Semicossyphus pulcher*, across an environmental gradient. Copeia 1990(3):787–795.
110	Crabtree, R. E., C. W. Harnden, D. Snodgrass, and C. Stevens. 1996. Age, growth, and mortality of bonefish, *Albula vulpes*, from the waters of the Florida Keys. Fish. Bull. 94:442–451.
111	Craig, M. T., D. J. Pondella II, and J. C. Hafner. 1999. Analysis of age and growth in two eastern Pacific groupers (Serranidae: Epinephelinae). Bull. Mar. Sci. 65(3):807–814.
112	Crane, J. M. 1981. Feeding and growth by the sessile larvae of the teleost *Porichthys notatus*. Copeia 1981(4):895–897.
113	Crawford, R. 1993. World record game fishes 1993. International Game Fish Association, Pompano Beach, FL.
114	Crooke, S. J. 1992. Yellowtail. *In* W. S. Leet, C. M. Dewees, and C. W. Haugen (eds.), California's living marine resources and their utilization, p 155–157. California Sea Grant Extension Program Publication UCSGEP-92-12. Univ. California Davis, Dept. Wildlife and Fisheries Biology.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
115	Cruz-Romero, M., E. Espino-Barr, J. Mimbela-Lopez, A. García-Boa, L. F. Obregon-Alcaraz, and E. Giron-Botello. 1991. Biologia reproductiva en tres especies del genero lutjanus en la costa de Colima, Mexico. CRIP-Manzanillo, Manzanillo, Mexico.
116	Cruz-Romero, M., E. Espino-Barr, and A. García-Boa. 1993. Aspectos poblacionales de cinco especies de la familia Haemulidae (Pisces) en la costa de Colima, Mexico. Inst. Nal. Pesca Sria. de Pesca, Mexico. Ciencia Pesquera 9:43–54.
117	Cucalón-Zenck, E. 1999. Growth and length-weight parameters of Pacific mackerel (*Scomber japonicus*) in the Gulf of Guayaguil, Ecuador. Naga ICLARM Q. 22(3):32–36.
118	Cudney-Bueno, R., M. Lavin, P. Raimondi, J. Torre, and P. Turk-Boyer. 2007. PANGAS field sampling database (updated 7 April 2007). Univ. Arizona, Tucson. (Available from R. Cudney-Bueno, David and Lucile Packard Foundation, 300 Second St., Los Altos, CA 94022.)
119	D'Agrosa, C., C. E. Lennert-Cody, and O. Vidal, 2000. Vaquita bycatch in Mexico's artisanal gill net fisheries: Driving a small population to extinction. Conserv. Biol. 14(4):1110–1119.
120	Davenport, S., and J. D. Stevens. 1988. Age and growth of two commercially important sharks (*Carcharinus tilstoni* and *C. sorrah*) from northern Australia. Aust. J. Mar. Freshw. Res. 39(4):417–433.
121	Davila-Ortiz, J. 2002. Biologia reproductiva de la raya *Mariposa gymnura marmorata* (Cooper 1863) en Bahia Almejas, B.C.S., Mexico. Tesis Profesional. Universidad Autónoma de Baja California, La Paz, BCS, Mexico.
122	De Anda-Montañez, A., F. Arreguin-Sanchez, and S. Martinez-Aguilar. 1999. Length-based growth estimates for Pacific sardine (*Sardinops sagax*) in the Gulf of California, Mexico. Calif. Coop. Ocean. Fish. Investig. Rep. 40:179–183.
123	De La Cruz Agüero, J. 1997. Catalogo de los peces marinos de Baja California Sur. IPN-CICIMAR, La Paz, Mexico.
124	DeLeon, S. 1999. Atherinidae. *In* J. Orsi (ed.), Report on the 1980–1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California, p. 217–248. Tech. Rep. No. 63. California Dept. Fish and Game, Sacramento.
125	DeMartini, E. E., A. M. Barnett, T. D. Johnson, and R. F. Ambrose. 1994. Growth and production estimates for biomass-dominant fishes on a southern California artificial reef. Bull. Mar. Sci. 55(2-3):484–500.
126	Díaz-Uribe, F. G., J. F. Elorduy-Garay, and M. T. González-Valdovinos. 2001. Age and growth of the leopard grouper, *Mycteroperca rosacea*, in the southern Gulf of California, Mexico. Pac. Sci. 55(2):171–182.
127	Díaz-Uribe, J. G., and R. C. S. Díaz-Uribe. 1989. Edad y crecimiento del Conejo, *Caulolatilus affinis* Gill 1865 (pisces: Branchiostegidae) en la Bahia de la Paz y sus alrededores, Baja California Sur, Mexico. Universidad Autónoma de Baja California, La Paz, BCS, Mexico.
128	Djabali, F., A. Mehailia, M. Koudil, and B. Brahmi. 1993. Empirical equations for the estimation of natural mortality in Mediterranean teleosts. Naga ICLARM Q. 16(1):35–37.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
129	Do Chi, T. (ed.). 1994. Groupe de travail ad hoc sur les sardinelles et autres especes de petits pelagiques cotiers de la zone nord du copace. COPACE/PACE/Ser. No. 91/58. FAO, Rome.
130	Dooley, J. K. 1978. Systematics and biology of the tilefishes (Perciformes: Branchiostegidae and Malacanthidae) with descriptions of two new species. U.S. Dept. Commer., NOAA Tech. Rep. NMFS Circ. No. 411:1–78.
131	Dorel, D. 1986. Poissons de l'Atlantique nord-est relations taille-poids. Institut Francais de Recherche pour l'Exploitation de la Mer, Issy-les-Moulineaux, Paris, France.
132	Drummond Sedgwick, S. 1982. The salmon handbook: The life and cultivation of fishes of the salmon family. Andre Deutsch Ltd., London.
133	Duarte, L. O., C. B. García, N. Sandoval, D. von Schiller, G. Melo, and P. Navajas. 1999. Length-weight relationships of demersal fishes from the Gulf of Salamanca, Colombia. Naga ICLARM Q. 22(1):34–36.
134	Dulcic, J., and M. Kraljevic. 1996. Weight-length relationship for 40 fish species in the eastern Adriatic (Croatian waters). Fish. Res. 28(3):243–251.
135	Dwiponggo, A., T. Hariati, S. Banon, M. L. Palomares, and D. Pauly. 1986. Growth, mortality, and recruitment of commercially important fishes and penaeid shrimps in Indonesian waters. ICLARM Tech. Rep. 17. International Center for Living Aquatic Resources Management, Manila, Philippines.
136	Edwards, R. R. C., A. Bakhader, and S. Shaher. 1985. Growth, mortality, age composition, and fishery yields of fish from the Gulf of Aden. J. Fish Biol. 27:13–21.
137	Emmett, R. L., S. A. Hinton, S. L. Stone, and M. E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries, vol. II: Species life history summaries. ELMR rep. 8. NOAA/NOS Strategic Environmental Assessments Division, Rockville, MD.
138	Erisman, B. E., M. L. Buckhorn, and P. A. Hastings. 2007. Spawning patterns in the leopard grouper, *Mycteroperca rosacea*, in comparison with other aggregating groupers. Mar. Biol. 151:1849–1861.
139	Erzini, K. 1991. A compilation of data on variability in length-age in marine fishes. Fisheries stock assessment, title XII. Collaborative Research Support Program, working paper 77. Univ. Rhode Island, Kingston.
140	Eschmeyer, W. N., and E. S. Herald. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co., Boston.
141	Eschmeyer, W. N. (ed.). 2000. Catalog of fishes. Updated database version of November 2000. Catalog databases as made available to FishBase in November 2000.
142	Evans, K., and M. A. Hindell. 2004. The age structure and growth of female sperm whales (*Physeter macrocephalus*) in southern Australian waters. J. Zool. 263:237–250.
143	Farrugio, H. 1975. Les muges (Poissons Téléostéens) de Tunisie. Répartition et Pêches. Contribution à leur étude systématique et biologique. Thesis. U.S.T.L. Montpellier, France.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
144	Feder, H. M., C. H. Turner, and C. Limbaugh. 1974. Observations on fishes associated with kelp beds in southern California. Calif. Dept. Fish Game Fish Bull. 160.
145	Fernholm, B. 1998. Hagfish systematics. *In* J. M. Jørgensen, J. P. Lomholt, R. E. Weber, and H. Malte (eds.), The biology of hagfishes, p. 33–44. Chapman & Hall, London.
146	Ferrero, R. C., and W. A. Walker. 1996. Age, growth, and reproductive patterns of the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) taken in high seas drift nets in the central north Pacific Ocean. Can. J. Zool. 74:1673–1687.
147	Fitch, J. E. 1956. Jack mackerel. Calif. Coop. Ocean. Fish Investig. Rep. 1955–1956:27–28.
148	Fitch, J. E. 1960. Black seabass. *In* California ocean fisheries resources to the year 1960, p. 48–49. California Dept. Fish and Game, Sacramento.
149	Fitch, J. E., and R. J. Lavenberg. 1968. Deep-water teleostean fishes of California. California Natural History Guides: 25. University of California Press, Berkeley and Los Angeles.
150	Fitch, J. E., and R. J. Lavenberg. 1971. Marine food and game fishes of California. University of California Press, Berkeley.
151	Fitch, J. E., and R. J. Lavenberg. 1975. Tidepool and nearshore fishes of California. University of California Press, Berkeley.
152	Flanagan, C. A., and J. R. Hendrickson. 1976. Observations on the commercial fishery and reproductive biology of the totaba, *Cynoscion macdonaldi*, in the northern Gulf of California. Fish. Bull. 74: 531–544.
153	Fletcher, W. J. 1990. A synopsis of the biology and exploitation of the Australasian pilchard, *Sardinops neopilchardus* (Steindachner). Part I: Biology. Fisheries Research Rep. 88. Western Australia Fisheries Dept., Perth.
154	Fletcher, W. J. 1995. Application of the otolith weight-age relationship for the pilchard, *Sardinops sagax neopilchardus*. Can. J. Fish. Aquat. Sci. 52(4):657–664.
155	Ford, R. F. 1965. Distribution, population dynamics, and behavior of a Bothid flatfish, *Citharichthys stigmaeus*. Doctoral dissertation. Univ. California San Diego.
156	Fowler, S. L. 2000. Whale shark *Rhincodon typus*: Policy and research scoping study. Nature Conservation Bureau, UK.
157	Franke, R., and A. Acero. 1996. Peces oseos comerciales del Parque Gorgona, *Pacifico colombiano* (Osteichthyes: Muraenesocidae, Hemiramphidae, Belonidae, Scorpaenidae, Triglidae, Malacanthidae, Gerreidae, Sparidae, Kyphosidae, Sphyraenidae e Istiophoridae). Revista de Biologia Tropical 44(2):763–770.
158	Frazer, N. B., and L. M. Ehrhart. 1985. Preliminary growth models for green, *Chelonia mydas*, and loggerhead, *Careetta caretta*, turtles in the wild. Copeia 1985:73–79.
159	Frey, H. W. (ed.). 1971. California's living marine resources and their utilization. Calif. Dept. Fish Game, Sacramento.
160	Frimodt, C. 1995. Multilingual illustrated guide to the world's commercial warmwater fish. Fishing News Books, Osney Mead, Oxford, UK.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
161	Fritzsche, R. A., and M. Schneider. 1995. Fistulariidae. Cornetas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1104–1105. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
162	Fritzsche, R. A., R. H. Chamberlain, and R. A. Fisher. 1985. Species profile: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific southwest): California grunion. U.S. Fish and Wildlife Service, biological rep. 82(11.28). U.S. Army Corp of Engineers, TR EL-82-4.
163	Froese, R., and D. Pauly (eds.). 2008. FishBase. World Wide Web electronic publication. Online at http://www.fishbase.org [accessed 23 February 2011].
164	Froese, R., and D. Pauly (eds.). 2008. FishBase. World Wide Web electronic publication. Online at http://www.fishbase.org [accessed 23 February 2011].
165	Froese, R., and D. Pauly (eds.). 2008. FishBase. World Wide Web electronic publication. Online at http://www.fishbase.org [accessed 23 February 2011].
166	García, C. B., L. O. Duarte, N. Sandoval, D. von Schiller, G. Melo, and P. Navajas. 1998. Length-weight relationships of demersal fishes form the Gulf of Salamanca, Colombia. Naga ICLARM Q.
167	García-Arteaga, J. P., R. Claro, and S. Valle. 1997. Length-weight relationships of Cuban marine fishes. Naga ICLARM Q. 20(1):38–43.
168	Garrison, K. J., and B. S. Miller. 1982. Review of the early life history of Puget Sound fishes. Contract No. 80-ABA-3680, unpubl. report FRI-UW-8216. Univ. Washington, School of Fisheries, Fisheries Research Institute, Seattle.
169	Getabu, A. 1987. Aspects of the Lake Victoria fisheries with emphasis on *Oreochromis niloticus* and *Alestes sadleri* from the Nyanza Gulf. U.N. Food and Agriculture Organization Fish. Rep. 389:416–431, FAO, Rome.
170	Gillanders, B. M., D. J. Ferrell, and N. L. Andrew. 1999. Aging methods for yellowtail kingfish, *Seriola lalandi*, and results from age-based and size-based growth models. Fish. Bull. 97:812–827.
171	Gómez C., L. A. Zapata, P. R. Franke, and G. E. Ramos. 1999. Hábitos alimentarios de *Epinephelus acanthistius* y notas de otros peces Serránidos capturados en el Parque Nacional Natural Gorgona, *Pacífico colombiano*. Boletín de Investigación Marina y Costera 28:43–60.
172	Gomon, M. F. 1995. Labridae. Viejas, doncellasas, señoritas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1201–1225. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
173	Gonçalves, J. M. S., L. Bentes, P. G. Lino, J. Ribeiro, A. V. M. Canário, and K. Erzini. 1997. Weight-length relationships for selected fish species of the small-scale demersal fisheries of the south and southwest coast of Portugal. Fish. Res. 30:253–256.
174	González-Acosta, F., and G. De La Cruz-Agüero. 2004. Length-weight relationships of fish species caught in a mangrove swamp in the Gulf of California (Mexico). J. Appl. Ichthyol. 20:154–155.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
175	Gracia-López, V., M. Kiewek-Martinez, M. Maldonado-García, P. Monsalvo-Spencer, G. Portillo-Clark, R. Civera-Cerecedo, M. Linares-Aranda, M. Robles-Mungaray, and J. M. Mazon-Suastegui. 2005. Larvae and juvenile production of the leopard grouper, *Mycteroperca rosacea* (Streets 1877). Aquacult. Res. 36:110–112.
176	Granados, R. R. 1958. Aspectos biologicos y economicos de la pesqueria de sardina (*Sardinops caerula* Girard 1854) en aguas Mexicanas del Pacifico. Sec. de Marina, Dir. Gen. de Pesca et Indust. Conex.
177	Grandcourt, E. M. 2002. Demographic characteristics of a selection of exploited reef fish from the Seychelles: Preliminary study. Mar. Freshw. Res. 53:123–130.
178	Gregory, P. A. 1992. Silversides. *In* W. S. Leet, C. M. Dewees, and C. W. Haugen (eds.), California's living marine resources and their utilization, p. 78–81. California Sea Grant Extension Program Publication UCSGEP-92-12. Univ. California Davis, Dept. Wildlife and Fisheries Biology.
179	Grismer, L. L. 2002. Amphibians and reptiles of Baja California, including its Pacific islands and the islands in the Sea of Cortes. University of California Press, Berkeley.
180	Grove, J. S., and R. J. Lavenberg. 1997. The fishes of the Galápagos Islands. Stanford University Press, Stanford, CA.
181	Gunderson. 1997 (cited in J. Field 2004). Application of ecosystem-based fishery management approaches in the northern California Current. Univ. Washington, Seattle.
182	Haedrich, R. L., and M. Schneider. 1995. Stromateidae. Palometas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1622–1624. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
183	Haimovici, M., and G. Velasco. 2000. Length-weight relationships of marine fishes from southern Brazil. Naga ICLARM Q. 23(1):19–23.
184	Hampton, J. 2000. Natural mortality rates in tropical tunas: Size really does matter. Can. J. Fish. Aquat. Sci. 57(5):1002–1010.
185	Harrison, T. D. 2001. Length-weight relationships of fishes from South African estuaries. J. Appl. Ichthyol. 17(1):46–48.
186	Hart, J. L. 1973. Pacific fishes of Canada. Fish. Res. Bd. Can. Bull. 180.
187	Heemstra, P. C., and J. E. Randall. 1993. Groupers of the world (Family Serranidae, Subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper, and lyretail species known to date. U.N. Food and Agriculture Organization Fisheries Synopsis 125:382. FAO, Rome.
188	Heemstra, P. C. 1995. Lobotidae. Dormilonas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1226. Pacifico Centro-Oriental. 3 vols. FAO, Rome.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
189	Heemstra, P. C. 1995. Serranidae. Meros, serranos, guasetas, enjambres, baquetas, indios, loros, gallinas, cabrillas, garropas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1565–1613. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
190	Hensley, D. A. 1995. Bothidae. Lenguados. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 931–936. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
191	Hensley, D. A. 1995. Paralichthyidae. Lenguados. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para ientification de especies para lo fines de la pesca, p. 1349–1380. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
192	Hoenig, J. M. 1979. The vertebral centra of sharks and their use in age determination. Master's thesis. Univ. Rhode Island, Kingston.
193	Holden, M. T. 1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. *In* F.R. Harden Jones (ed.), Sea fisheries research, p. 117–137. Elek Scientific Books Ltd., London.
194	Holt, S. J. 1960. A preliminary comparative study of the growth, maturity, and mortality of sardines. *In* H. Rosa Jr. and G. Murphy (eds.), Proceedings of the World Scientific Meeting. Biology sardines and related species, 9(2)553–561, Subject synops. (2). FAO, Rome.
195	Hugg, D. O. 1996. MAPFISH georeferenced mapping database. Freshwater and estuarine fishes of North America. Life Science Software. (Available from Dennis O. Hugg and Steven Hugg, 1278 Turkey Point Road, Edgewater, MD 21037.)
196	Humann, P., and N. Deloach. 1993. Reef fish identification. Galápagos. New World Publications Inc., Jacksonville, FL.
197	Ibáñez-Aguirre, A. L., and M. Gallardo-Cabello. 1996. Age determination of the gray mullet *Mugil cephalus* and the white mullet *Mugil curema* (pisces: Mugilidae) in Tamiahua Lagoon, Veracruz. Cienc. Mar. 22:329–345.
198	IGFA (International Game Fish Association). 2001. Database of IGFA angling records until 2001. IGFA, Fort Lauderdale, FL.
199	Ih-Hsiu Tung. 1970. Studies on the fishery biology of the gray mullet, *Mugil cephalus*, in Taiwan. *In* J.C. Marr (ed.), The Kuroshio: A symposium on Japan current, p. 491–504. East West Center Press, Honolulu.
200	Ingles, J., and D. Pauly. 1984. An atlas of the growth, mortality, and recruitment of Philippines fishes. ICLARM Tech. Rep. 13. International Center for Living Aquatic Resources Management, Manila, Philippines.
201	Instituto Nacional de la Pesca. 2000. Sustentabilidad y pesca responsable en Mexico; Evaluación y manejo: La pesquería de sierra del Pacifico, p. 259–274. SAGARPA. Mexico, DF.
202	Jabat, M., and P. Dalzell. 1988. Preliminary stock assessment of the Davao ring net fishery for bullet tunas and small pelagic fishes in the Camotes Sea, Central Visayas, Philippines. BFAR Tech. Pap. 11(1).

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
203	Jagielo, T., F. R. Wallace, and Y. W. Cheng. 2003. Assessment of lingcod (*Ophiodon elongatus*) for the Pacific Fishery Management Council in 2003. Pacific Fishery Management Council, Portland, OR.
204	Jingran, Z., and K. S. Misra. 1962. Further fish-tagging experiments in Chilka Lake, with special reference to *Mugil cephalus* Linnaeus. Indian J. Fish. 9(2):129–197.
205	Johnsgard, P. 1993. Cormorants, darters, and pelicans of the world. Smithsonian Institution, Washington, DC.
206	Joseph, J., and T. Calkins. 1969. Population dynamics of the skipjack tuna (*Katsuwonus pelamis*) in the eastern Pacific Ocean. Bull. Inter-Amer. Trop. Tuna Comm. 13:1–273.
207	Joseph, J. 1963. Contribution to the biology of the engraulid *Anchoa naso* (Gilbert and Pierson 1898) from Ecuadorian waters. Bull. Inter-Amer. Trop. Tuna Comm. 8:1–30.
208	Kailola, P. J., and W. A. Bussing. 1995. Ariidae. *Bagres marinos*. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 860–886. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
209	Kailola, P. J., M. J. Williams, P. C. Stewart, R. E. Reichelt, A. McNee, and C. Grieve. 1993. Australian fisheries resources. Bureau of Resource Sciences, Canberra, Australia.
210	Kasim, H. M., K. M. S. Ameer Hamsa, T. S. Balasubramanian, and S. Rajapackiam. 1996. Fishery of full beaks and half beaks with special reference on the growth, mortality, and stock assessment of *Ablennes hians* (Valenciennes) along the Tuticorin coast, Gulf of Mannar. Indian J. Fish. 43:51–59.
211	Kato, S. 1991. Ocean whitefish. *In* W. S. Leet, C. M. Dewees, and C. W. Haugen (eds.), California's living marine resources and their utilization, p. 201–202. California Sea Grant Extension Program Publication UCSGEP-92-12. Univ. California Davis, Dept. Wildlife and Fisheries Biology, Davis.
212	Kawasaki, T. 1963. The growth of skipjack on the northeastern Sea of Japan. Bull. Tohoku Res. Fish. Lab. (23):44–60.
213	Killam, K. A., and G. R. Parsons. 1989. Age and growth of the blacktip shark, *Carcharinus limbatus*, near Tampa Bay, Florida. Fish. Bull. 87:845–857.
214	Kim, B. G., A. C. Ostrowski, and C. Brownell. 1993. Review of hatchery design and techniques used at the Oceanic Institute for intensive culture of the mahimahi (*Coryphaena hippurus*) on a commercial scale. *In* C. S. Lee, M. S. Su, and I. C. Liao (eds.), Finfish hatchery in Asia: Proceedings of finfish hatchery in Asia 1991, p. 179–190. TML Conf. Proc. 3. Tungkang Marine Laboratory, Taiwan Fisheries Research Institute.
215	King, R. P. 1996. Length-weight relationships of Nigerian coastal water fishes. Naga ICLARM Q. 19(4):53–58.
216	King, R. P. 1997. Growth performance of Nigerian fish stocks. Naga ICLARM Q. 20(2):31–35.
217	Klausewitz, W., J. E. McCosker, J. E. Randall, and H. Zetsche. 1978. *Hoplolatilus chlupatyi* n. sp., un nouveau poisson marin des Philippines (Pisces, Perciformes, Percoidei, Branchiostegidae) (with English summary). Rev. fr. Aquariol. 2:30.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
218	Klinger, R. C., and J. A. Musick. 1995. Age and growth of loggerhead turtles (*Caretta caretta*) from Chesapeake Bay. Copeia 1995:204–209.
219	Knaggs, E. H., and R. H. Parrish. 1973. Maturation and growth of Pacific mackerel, *Scomber japonicus* Houttuyn. Calif. Fish Game 59:114–120.
220	Kochzius, M. 1997. Length-weight relationship of fishes from a sea grass meadow in Negros Oriental, Philippines. Naga ICLARM Q. 20(3/4):64–65.
221	Kohler, N. E., J. G. Casey, and P. A. Turner. 1995. Length-weight relationships for 13 species of sharks from the western North Atlantic. Fish. Bull. 93:412–418.
222	Kong I., R. Meléndez, and G. Henriquez. 1988. Los peces Ophidiiformes de aguas profundas entre Arica (18°19′S) e Isla Mocha (38°30′S). Estudios Oceanologicos 7:1–15.
223	Kramer, S. H., and J. S. Sunada. 1992. Flatfishes: California halibut. *In* W. S. Leet, C. M. Dewees, and C. W. Haugen (eds.), California's living marine resources and their utilization, p. 94–97. California Sea Grant Extension Program Publication UCSGEP-92-12. Univ. California Davis, Dept. Wildlife and Fisheries Biology.
224	Krupp, F., and W. Schneider. 1995. Pomacanthidae. Angeles. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1388–1391. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
225	Krupp, F. 1995. Acanthuridae. Sangradores, cirujanos, navajones. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K.E. Carpenter and V. Niem (eds.), Guia FAO para Identification de Especies para lo Fines de la Pesca, p. 839–844. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
226	Krupp, F. 1995. Achiridae. Suelas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 845–850. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
227	Kulbicki, M., G. Mou Tham, P. Thollot, and L. Wantiez. 1993. Length-weight relationships of fish from the lagoon of New Caledonia. Naga ICLARM Q. 16(2-3):26–29.
228	Kuo, C.-M., Z. H. Shehadeh, and K. K. Milisen. 1973. A preliminary report on the development, growth, and survival of laboratory reared larvae of the gray mullet, *Mugil cephalus*. Fish Biol. 5:459–470.
229	Kurogane, K. 1974. Review of mackerel resources of the western Pacific. 15th Indo-Pacific Fish Conference Proceedings, Wellington, New Zealand, 18–27 October 1972. Sect. III:253–264.
230	Kusher, D. I., S. E. Smith, and G. M. Cailliet. 1992. Validated age and growth of the leopard shark, *Triakis semifasciata*, with comments on reproduction. Environ. Biol. Fish. 35:187–203.
231	Kwok, K. Y., and I. H. Ni. 2000. Age and growth of cutlassfishes, *Trichiurus* spp. from the South China Sea. Fish. Bull. 98:748–758.
232	Langi, S. A., T. F. Latu, and S. Tulua. 1992. Preliminary study of the biology of mullets from Nuku'alofa, Tonga. Papers on fisheries science from the Pacific Islands. South Pacific Commission, Nouméa, New Caledonia 1:37–42.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
233	Lasso, J., and L. Zapata. 1999. Fisheries and biology of *Coryphaena hippurus* (Pisces: Coryphaenidae) in the Pacific coast of Colombia and Panama. Sci. Mar. 63(3-4):387–399.
234	Last, P. R., and J. D. Stevens. 1994. Sharks and rays of Australia. Commonwealth Scientific and Industrial Research Organization, Collingwood, Victoria, Australia.
235	Lavapie-Gonzales, F., S. R. Ganaden, and F. C. Gayanilo Jr. 1997. Some population parameters of commercially important fishes in the Philippines. Bureau of Fisheries and Aquatic Resources, Manila, Philippines.
236	Lavenberg, R. J., and M. Chernoff. 1995. Atherinidae. Pejerreyes. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.). Guia FAO para identification de especies para lo fines de la pesca, p. 889–901. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
237	Lavenberg, R. J. 1988. Chlopsid eels of the eastern Pacific with a new species and descriptions of larval forms. Bull. Mar. Sci. 42(2):253–264.
238	Lea, R. N. 1995. Ophidiidae. Brótolas, congriperlas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.) Guia FAO para identification de especies para lo fines de la pesca, p. 1342–1348. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
239	Leis, J. M. 1986. Diodontidae. *In* M. M. Smith and P. C. Heemstra (eds.) Smiths' sea fishes, p. 903–907. Springer-Verlag, Berlin.
240	Leong, R. 1984. Growth of jack mackerel, *Trachurus symmetricus*, in captivity. Calif. Coop. Ocean. Fish. Investig. Rep. 25:146–150.
241	Lessa, R., and F. M. Santana. 1998. Age determination and growth of the smalltail shark, *Carcharhinus porosus*, from northern Brazil. Mar. Freshw. Res. 49(7):705–711.
242	Letourneur, Y., M. Kulbicki, and P. Labrosse. 1998. Length-weight relationships of fish from coral reefs and lagoons of New Caledonia, southwestern Pacific Ocean: An update. Naga ICLARM Q. 21(4):39–46.
243	Letourneur, Y. 1998. First length-weight relationships of some marine fish species of Réunion Island, southwest Indian Ocean. Naga ICLARM Q. 21(4):37–39.
244	Li, K.-M., P.-J. Chiang, and C.-T. Chen. 1998. Age and growth estimates of the bigeye thresher shark, *Alopias superciliosus*, in northeastern Taiwan waters. Fish. Bull. 96(3):482–491.
245	Lieske, E., and R. Myers. 1994. Collins pocket guide. Coral reef fishes. Indo-Pacific and Caribbean including the Red Sea. Harper Collins Publishers, New York.
246	Limbaugh, C. 1955. Fish life in the kelp beds and the effects of kelp harvesting. IMR Reference 55–9. Univ. California La Jolla, Institute of Marine Resources.
247	Limbaugh, C. 1964. Notes on the life history of two Californian pomacentrids: Garabaldis, *Hypsypops rubicunda* (Girard), and blacksmiths, *Chromis punctipinnis* (Cooper). Pac. Sci. 18:41–50.
248	Limbaugh, C. 1961. Life history and ecological notes on the black croaker. Calif. Fish Game 41:163–174.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
249	Liu, K.-M., C.-T. Chen, T.-H. Liao, and S.-J. Joung. 1999. Age, growth, and reproduction of the pelagic thresher shark, *Alopia pelagicus*, in the northwestern Pacific. Copeia 1999(1):68–74.
250	López-Peralta, R. H., and C. A. T. Arcila. 2002. Diet composition of fish species from the southern continental shelf of Colombia. Naga, WorldFish Center Q. 25(3&4):23–29.
251	Love, M. 1992. California scorpionfish. *In* W. S. Leet, C. M. Dewees, and C. W. Haugen (eds.), California's living marine resources and their utilization, p. 133–135. California Sea Grant Extension Program Publication UCSGEP-92-12. Univ. California Davis, Dept. Wildlife and Fisheries Biology.
252	Love, M. 1996. Probably more than you want to know about the fishes of the Pacific Coast. Really Big Press, Santa Barbara, CA.
253	Love, M. S., B. Axell, P. Morris, R. Collins, and A. Brooks. 1987. Life history and fishery of the California scorpionfish, *Scorpaena guttata*, within the southern California bight. Fish. Bull. 85(1):99–115.
254	Love, M. S., L. Thorsteinson, C. W. Mecklenburg, and T. A. Mecklenburg. 2000. A checklist of marine and estuarine fishes of the northeast Pacific from Alaska to Baja California. U.S. Geophysical Service, National Biological Service, Seattle, WA.
255	MacNair, L. S., M. L. Domeier, and C. S. Y. Chun. 2001. Age, growth, and mortality of California halibut, *Paralichthys californicus*, along southern and central California. Fish. Bull. 99:588–600.
256	Magnússon, J., and J. V. V. Magnússon. 1987. ICEIDA/Cape Verde Islands Fisheries Project. Survey of demersal fish resources in the waters off Cape Verde Islands. IV. Report: Summary of information on species. Icelandic International Development Agency, Marine Research Institute, Reykjavik.
257	Manooch, C. S. 1987. Age and growth of snappers and groupers. *In* J. J. Polovina and S. Ralston (eds.), Tropical snappers and groupers: Biology and fisheries management, p. 329–373. Ocean Resour. Mar. Policy Ser. Westview Press Inc., Boulder and London.
258	Mariano-Melendez, E. 1997. Biologia reproductiva de la raya *Lodera dasyatis* Brevis (garman, 1880), en Bahia Almejas, Baja California Sur, Mexico. Universidad Autónoma de Baja California, La Paz, BCS, Mexico.
259	Markle, D. F., and J. E. Olney. 1990. Systematics of the pearlfishes (Pisces: Carapidae). Bull. Mar. Sci. 47(2):269–410.
260	Martin, L. K., and G. M. Cailliet. 1988. Age and growth determination of the bat ray, *Myliobatis californica* Gill, in central California. Copeia 1988(3):762–773.
261	Masuda, H., K. Amaoka, C. Araga, T. Uyeno, and T. Yoshino. 1984. The fishes of the Japanese Archipelago. Vol. 1 (text). Tokai University Press, Tokyo.
262	Matheson III, R. H., and G. R. Huntsman. 1984. Growth, mortality, and yield-per-recruit models for speckled hind and snowy grouper from the United States, South Atlantic Bight. Trans. Am. Fish. Soc. 113:607–616.
263	Matsui, T., and R. H. Rosenblatt. 1984. Review of the deep-sea fish family Platytroctidae (Pisces: Salmoniformes). Bull. Scripps Inst. Oceanogr. 26(1–7):1–59.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
264	Matsumoto, W. M., R. A. Skillman, and A. E. Dizon. 1984. Synopsis of biological data on the skipjack tuna, *Katsuwonus pelamis*. U.S. Dept. Commer., NOAA Tech. Rep. NMFS Circular 451.
265	Maxwell, W. D. 1975. The croakers of California. California Marine Resources Leaflet 8. California Dept. Fish and Game, Sacramento.
266	Mayers, L. J. 1971. Chromosome analysis of some members of the genus *Salvelinus*. Diss. Abstr. 32(5):3079.
267	McCosker, J. E., and R. H. Rosenblatt. 1995. Muraenidae. Morenas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1303–1315. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
268	McCosker, J. E., and R. H. Rosenblatt. 1995. Ophichthidae. Tiesos, serpentones. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para Identification de Especies para lo Fines de la Pesca, p. 1326–1341. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
269	McEachran, J. D., and G. Notarbartolo di Sciara. 1995. Myliobatidae. Aguilas marinas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para los fines de la pesca, p. 765–768. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
270	McEachran, J. D. 1995. Gymnuridae. Rayas-mariposa, tuyos. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para los fines de la pesca, p. 756–758. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
271	McEachran, J. D. 1995. Narcinidae. Rayas eléctricas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para los fines de la pesca, p 769–771. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
272	McEachran, J. D. 1995. Rajidae. Rayas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para los fines de la pesca, p. 773–777. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
273	McEachran, J. D. 1995. Rhinobatidae. Peces guitarra. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para los fines de la pesca, p. 778–781. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
274	McEachran, J. D. 1995. Urolophidae. Rayas redondas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para los fines de la pesca, p. 786–792. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
275	McKay, R. J., and M. Schneider. 1995. Haemulidae. Burros, corocoros, chulas, gallinazos, roncos. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1136–1173. Pacifico Centro-Oriental. 3 vols. FAO, Rome.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
276	Medina-Gómez, S. P. 2006. Edad y crecimiento de la sierra del Pacifico *Scomberomorus sierra* (Jordan y Starks 1895), en el Golfo de California, Mexico. Tesis de Maestría. CICIMAR-IPN. La Paz, BCS, Mexico.
277	Mejia-Salazar, L. A. 2007. Biología reproductiva del cazon bironche, *Rhizoprionodon longurio* (Jordan and Gilbert 1882) en el Pacifico Mexicano. Tesis de Maestría. CICIMAR-IPN. La Paz, BCS, Mexico.
278	Mendieta, A., and M. Samamé. 1984. Avance de las investigaciones del 'vocador' *Prionotus stephanophrys* L. en el area de su distribucion. *In* Libro de resumenes, p. 17. I Congreso Nacional de Biologia Pesquera, 28 de Junio al 01 de Julio, 1984. Colegio de Biologos Regional del Norte, Trujillo, Peru.
279	Mendo, J. A. 1984. Edad, crecimiento, y algunos aspectos reproductivos y alimentarios de la caballa (*Scomber japonicus peruanus*). Bol. Inst. Mar. Peru 8:101–156.
280	Merlen, G. 1988. A field guide to the fishes of Galapagos. Wilmot Books, London.
281	Merret, N. R. 1968. Weight-length relationship for certain scombroid fishes from the equatorial western Indian Ocean. East Afr. Agric. For. J. 34(2):165–169.
282	Miller, D. J., and R. N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish Game Fish Bull. 157.
283	Miya, M., and D. F. Markle. 1993. *Baja California aequatoris*, new species of alepocephalid fish (Pisces: Salmoniformes) from the central equatorial Pacific. Copeia 1993(3):743–747.
284	Mizroch, S. A., L. M. Herman, J. M. Straley, D. A. Glockner-Ferrari, C. Jurasz, J. Darling, S. Cerchio, C. M. Gabriele, D. R. Salden, and O. Von Ziegesar. 2004. Estimating the adult survival rate of central north Pacific humpback whales (*Megaptera novaeangliae*). J. Mammal. 85:963–972.
285	Mollet, H. E., and G. M. Cailliet. 1996. Using allometry to predict body mass from linear measurements of the white shark. *In* A. P. Klimley and D. G. Ainley (eds.), Great white sharks, p. 81–90. The biology of *Carcharodon carcharias*. Academic Press Inc., San Diego.
286	Mooney-Seus, M. L., and G. S. Stone. 1997. The forgotten giants: Giant ocean fishes of the Atlantic and the Pacific. Ocean Wildlife Campaign, Washington, DC. New England Aquarium, Boston.
287	Moore, C. M., and R. F. Labisky. 1984. Population parameters of a relatively unexploited stock of snowy groupers in the lower Florida Keys. Trans. Am. Fish. Soc. 113:322–329.
288	Morales-Zárate, M. V., F. Arreguín-Sánchez, J. López-Martínez, and S. E. Lluch-Cota. 2004. Ecosystem trophic structure and energy flux in the northern Gulf of California, Mexico. Ecol. Model. 174:331–345.
289	Mortimer, J. A., M. Donnelly, and P. T. Plotkin. 2000. Sea turtles. *In* C. R. C. Sheppard (ed.), Seas at the millennium: An environmental evaluation, p. 59–71. Vol. 3: Global issues and processes. Pergamon, Oxford.
290	Moser, H. G. 1996. Scorpaenidae: Scorpionfishes and rockfishes. *In* H. G. Moser (ed.), The early stages of fishes in the California Current region, p. 733–795. Calif. Coop. Ocean. Fish. Investig. Rep., Atlas No. 33. Allen Press Inc., Lawrence, KS.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
291	Muhlia-Melo, A. 1980. Sinopsis sobre los datos biológicos del barrilete negro, *Euthynnus lineatus* (Kishinouye, 1920), en el Océano Pacífico. Rev. Com. Perm. Pacifico Sur 11:229–246.
292	Munro, J. L., and D. M. Williams. 1985. Assessment and management of coral reef fisheries: Biological, environmental, and socio-economic aspects. *In* Proceedings of the Fifth International Coral Reef Congress, Tahiti, 27 May–1 June 1985. Vol. 4, p. 543–578. Antenne Museum-EPHE, Moonea, French Polynesia.
293	Munroe, T. A., F. Krupp and M. Schneider. 1995. Cynoglossidae. Lenguas, lenguetas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1039–1059. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
294	Murty, V. S. 2002. Marine ornamental fish resources of Lakshadweep. CMFRI Spec. Publ. No. 72. Central Marine Fisheries Research Institute, Kochi, India.
295	Musick, J. 1999. Life in the slow lane: Ecology and conservation of long-lived marine animals. Am. Fish. Soc. Symp. 23:1–10.
296	Muus, B. J., and J. G. Nielsen. 1999. Sea fish. Scandinavian Fishing Year Book, Hedehusene, Denmark.
297	Myers, R. F. 1991. Micronesian reef fishes. 2nd edition. Coral Graphics, Barrigada, Guam.
298	Narasimham, K. A. 1976. Age and growth of ribbonfish *Trichiurus lepturus* Linnaeus. Indian J. Fish. 23(1/2):174–182.
299	Natanson, L. J., J. G. Casey, and N. E. Kohler. 1995. Age and growth estimates for the dusky shark, *Carcharhinus obscurus*, in the western North Atlantic Ocean. Fish. Bull. 93:116–126.
300	Neal, T. J. 1993. A test of the function of juvenile color patterns in the pomacentrid fish *Hypsypops rubicundus* (Teleostei: Pomacentridae). Pac. Sci. 47(3):240–247.
301	Newman, G. 1970. Stock assessment of the pilchard *Sardinops ocellata* at Walvis Bay, southwest Africa. Div. Fish. Invest. Rep. 85:1–14.
302	Nigrelli, R. F. 1959. Longevity of fishes in captivity, with special reference to those kept in the New York Aquarium. *In* G. E. W. Wolstehnolmen and M. O'Connor (eds.), CIBA Foundation Colloquium on Ageing: The life span of animals. Vol. 5, p. 212–230. Churchill, London.
303	Noren, D. Unpubl. data. Cited in E. J. Brand, I. C. Kaplan, C. J. Harvey, P. S. Levin, E. A. Fulton, A. J. Hermann, and J. C. Field. 2007. A spatially explicit ecosystem model of the California current's food web and oceanography. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-84.
304	Olsen, E., and J. Sunde. 2002. Age determination of minke whales (*Balaenoptera acutorostrata*) using the aspartic acid racemization technique. Sarsia 87(1):1–8.
305	Orlov, A., and C. Binohlan. 2009. Length-weight relationships of deep-sea fishes from the western Bering Sea. J. Appl. Ichthyol. 25:223–227.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
306	Osorno, J. L., and T. Szekely. 2003. Sexual conflict and parental care in magnificent frigatebirds: Full compensation by deserted females. Anim. Behav. 68:337–342.
307	Oxenford, H. A. 1986. A preliminary investigation of the stock of the dolphin, *Coryphaena hippurus*, in the western central Atlantic. Fish. Bull. 84(2):451–460.
308	Oxenford, H. A. 1999. Biology of the dolphinfish (*Coryphaena hippurus*) in the western central Atlantic: A review. Sci. Mar. 63(3/4):277–301.
309	Padilla, J. E. 1991. Managing tropical multispecies fisheries with multiple objectives. Doctoral dissertation. Simon Fraser University, Burnaby, BC, Canada.
310	Pakoa, K. 1998. Vital statistics of marine fishes of Vanuatu. Naga ICLARM Q (Apr.-Sep.):27–29.
311	Palacios, J. A., and P. C. Phillips. 1984. Análisis de la estructura poblacional de Anchoa panamensis (Steindachner, 1875) en el Golfo de Nicoya, Costa Rica. Rev. Biol. Trop., 32(1):77–84.
312	Palko, B. J., G. L. Beardsley, and W. Richards. 1982. Synopsis of the biological data on dolphin-fishes, *Coryphaena hippurus* Linnaeus and *Coryphaena equiselis* Linnaeus. FAO Fish. Synop. (130). U.S. Dept. Commer., NOAA Tech. Rep. NMFS Circ. 443.
313	Parin, N. V. 1995. Exocoetidae. Peces voladores. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1091–1103. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
314	Parrish, R. H., and A. D. MacCall. 1978. Climatic variation and exploitation in the Pacific mackerel fishery. Calif. Dept. Fish Game Fish Bull. 167.
315	Parsons, G. R., and K. M. Peters. 1989. Age determination in larval and juvenile sheepshead, *Archosargus probatocephalus*. Fish. Bull. U.S. 87:985–988.
316	Patterson, K. R., and J. Martinez. 1991. Exploitation of the dolphin-fish *Coryphaena hippurus* L. off Ecuador: Analysis by length-based virtual population analysis. Fishbyte 9(2):21–23.
317	Paulin, C. 1995. Moridae. Moras, molleras, carboneros. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1281–1299. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
318	Pauly, D., A. Cabanban, and F. S. B. Torres Jr. 1996. Fishery biology of 40 trawl-caught teleosts of western Indonesia. *In* D. Pauly and P. Martosubroto (eds.), Baseline studies of biodiversity: The fish resource of western Indonesia, p. 135–216. ICLARM Studies and Reviews 23. International Center for Living Aquatic Resources Management, now known as WorldFish Center, Penang, Malaysia.
319	Pauly, D., A. C. de Vildoso, J. Mejia, M. Samamé, and M. L. Palomares. 1987. Population dynamics and estimated anchoveta consumption of bonito (*Sarda chiliensis*) off Peru, 1953 to 1982. *In* D. Pauly and I. Tsukayama (eds.), The Peruvian anchoveta and its upwelling ecosystem: Three decades of change, p. 248–267. ICLARM Stud. Rev. 15. IMARPE, Callao, Peru; GTZ, GmbH Eschborn, Federal Republic of Germany; International Center for Living Aquatic Resources Management, Manila, Philippines.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
320	Pauly, D., R. Froese, and J. S. Albert. 1998. The BRAINS table. *In* R. Froese and D. Pauly (eds.), FishBase 98: Concepts, design, and data sources, p. 195–198. International Center for Living Aquatic Resources Management, now known as WorldFish Center, Penang, Malaysia.
321	Pauly, D. 1978. A preliminary compilation of fish length growth parameters. Ber. Inst. Meereskd. Christian-Albrechts Univ., Kiel, Germany 55:1–200.
322	Pauly, D. 1979. Gill size and temperature as governing factors in fish growth: A generalization of von Bertalanffy's growth formula. Berichte des Instituts für Meereskunde an der Christian-Albrechts Univ., Kiel, Germany.
323	Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. CIEM 39(2):175–192.
324	Pauly, D. 1997. Growth and mortality of basking shark *Cethorhinus maximus*, and their implications for whale shark *Rhincodon typus*. Master's thesis. Presented at the International Seminar on Shark and Ray Biodiversity, Conservation, and Management, Kota Kinabalu, Sabah, Malaysia, 7–10 July 1997.
325	Perrin, W., B. Wursig, and H. Thewissen (eds.). 2002. Encyclopedia of marine mammals. Academic Press, San Diego, CA.
326	Perrotta, R. G. 1992. Growth of mackerel (*Scomber japonicus* Houttuyn 1782) from the Buenos Aires-north Patagonian region (Argentine Sea). Sci. Mar. 56(1):7–16.
327	Philbrick, C. 1988. Length frequency analysis of pelagic fish species. Fishbyte 6(3):5–6.
328	Phillips, A. C. 1973. Age determination and growth rate studies of the northern midshipman (*Porichthys notatus* Girard). Bachelor's thesis. Univ. Victoria, BC, Canada.
329	Pillay, P. P., and G. Gopakumar. 1989. Stock assessment of migratory fish species based on localized data–Oceanic skipjack tuna pole and line fishery at Minicoy as a case study. *In* S. C. Venema and N. P. van Zalinge (eds.), Contributions to tropical fish stock assessment in India, p. 127–142. FAO/DANIDA/ICAR National Follow-up Training Course on Fish Stock Assessment, Cochin, India, 2–28 November 1987. FI:GCP/INT/392/DEN/1.
330	Pinkas, L. 1960. White seabass. California ocean fisheries resources to the year 1960. California Dept. Fish and Game, Sacramento.
331	Pinkas, L. 1966. A management study of the California barracuda *Sphyraena argentea* Girard. Calif. Dept. Fish Game Fish Bull. 134.
332	Pó, L. A., C. Dionísio, and R. Paula e Silva. 1992. Growth of skipjack *Katsuwonus pelamis* from Mozambique. Rev. Invest. Pesq. (Maputo) 21:98–105.
333	Poss, S. G. 1995. Scorpaenidae. Rascacios, chancharros. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1544–1564. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
334	Powell, D. C. 2001. A fascination for fish: Adventures of an underwater pioneer. University of California Press, Berkeley.
335	Pratt Jr., H. L., and J. G. Casey. 1983. Age and growth of the shortfin mako, *Isurus oxyrinchus*, using four methods. Can. J. Fish. Aquat. Sci. 40:1944–1957.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
336	Quast, J. C. 1968. Fish fauna of the rocky inshore zone. Calif. Dept. Fish Game Fish Bull. 139:35–55.
337	Quéro, J.-C., T. Matsui, R. H. Rosenblatt, and Y. I. Sazonov. 1990. Platytroctidae. *In* J.-C. Quero, J. C. Hureau, C. Karrer, A. Post, and L. Saldanha (eds.), Checklist of the fishes of the eastern tropical Atlantic (CLOFETA), p. 265–274. Vol. 1. JNICT, Lisbon; SEI, Paris; and UNESCO, Paris.
338	R. Cudney-Bueno. 2008. The David and Lucile Packard Foundation, Los Altos, CA.
339	Rackowski, J. P., and E. K. Pikitch. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific southwest). Pacific and speckled sanddabs. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.107).
340	Rafail, S. Z. 1972. A statistical study of length-weight relationship of eight Egyptian fishes. Bull. Inst. Oceanogr. Fish. (Cairo) 2:136–156.
341	Randall, J. E., and C. C. Baldwin. 1997. Revision of the serranid fishes of the subtribe Pseudogrammina, with descriptions of five new species. Indo-Pacific Fishes (26):1–56.
342	Randall, J. E., G. R. Allen, and R. C. Steene. 1990. Fishes of the Great Barrier Reef and Coral Sea. University of Hawaii Press, Honolulu.
343	Randall, J. E. 1961. A contribution to the biology of the convict surgeonfish of the Hawaiian Islands: *Acanthurus triostegus sandvicensis*. Pac. Sci. 15(2):215–272.
344	Randall, J. E. 1983. Size of the great white shark (Carcharodon). Science (Wash.) 181:169–170.
345	Reed, A. J., and A. D. MacCall. 1988. Changing the size limit: How could it affect California halibut fisheries. Calif. Coop. Ocean. Fish. Investig. Rep. 24:158–166.
346	Reichert, M. J. M. 1998. *Etropus crossotus*, an annual flatfish species; Age and growth of the fringed flounder in South Carolina. J. Sea Res. 40(3/4):323–332.
347	Reichert, M. J. M. 2000. On the life history of the fringed flounder (*Etropus crossotus*), a small tropical flatfish in the South Atlantic Bight. Doctoral dissertation. Rijksuniversiteit Groningen, The Netherlands.
348	Reina, R. D., P. A. Mayor, J. R. Spotila, R. Piedra, and F. V. Paladino. 2002. Nesting ecology of the leatherback turtle, *Dermochelys coriacea*, at Parque Nacional Marino las Baulas, Costa Rica: 1988–1989 to 1999–2000. Copeia 3:653–664.
349	Reñones, O., B. Morales-Nin and S. Deudero. 1999. Population size structure, age, and growth of *Naucrates ductor* in the small scale FADs fishery of Mallorca Island (western Mediterranean). Sci. Mar. 63(3-4):355–366.
350	Reynolds, W. W., D. A. Thomson, and M. E. Casterlin. 1976. Temperature and salinity tolerances of larval California grunion, *Leuresthes tenuis* (Ayres): A comparison with gulf grunion, *L. sardina* (Jenkins and Evermann). J. Exp. Mar. Biol. Ecol. 24:73–82.
351	Kastelle, C. R., K. E. W. Shelden, and D. K. Kimura. 2003. Age determination of mysticete whales using $^{210}Pb/^{226}Ra$ disequilibria. Can. J. Zool. 81:21–32.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
352	Rodriguez-Lorenzo, S. 2007. Edad y crecimiento de la raya *Mariposa gymnura marmorata* (Cooper 1863) del alto Golfo de California, Mexico. Tesis Maestria. Universidad Autónoma de Baja California, Ensenada, BC, Mexico.
353	Rodríguez-Quiroz, G., and E. A. Aragón-Noriega. 2007. Artisanal fishing of bigeye croaker *Micropogonias megalops* (Gilbert 1890) within the biosphere reserve of the upper Gulf of California and vaquita refuge area. Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional, Unidad Sinaloa.
354	Rojas, P. A. 2004. Hacia un manejo sostenible de las poblaciones ícticas demersales del Parque Nacional Natural Gorgona y su área de Influencia con el respaldo de los actores sociales involucrados. Aspectos biológicos y pesqueros.
355	Rojas, P. A., C. Gutiérrez, F., V. Puentes, A. A. Villa, and E. A. Rubio. 2004. Aspectos de la biología y dinámica poblacional del pargo coliamarillo *Lutjanus argentiventris* en el Parque Nacional Natural Gorgona, Colombia. Investigaciones Marinas, Valparaíso 32:23–36.
356	Rojas-Bracho, L., R. R. Reeves, A. Jaramillo-Legorreta, and B. L. Taylor. 2007. *Phocoena sinus*. IUCN red list of threatened species. Online at http://www.iucnredlist.org/apps/redlist/details/17028/0 [accessed 28 October 2010].
357	Romero, M. C., E. E. Barr, and A. G. Boa. 1987. Algunos aspectos biológico-pesqueros de la cabrilla *Epinephelus labriformes* (Jenyns, 1842). Acta Cientifica Potosina 9(2):165–176.
358	Romo-Curiel, A. E. 2004. Biologia reproductiva del pez guitarra *Rhinobatus productus* Ayres, 1856 (chondrichthyes: Rhinobatidae) en la region norte del Golfo de California, Mexico. Universidad Autónoma de Baja California, Ensenada, BC, Mexico.
359	Ronquillo, I. A. 1975. A review of the roundscad fishery in the Philippines. Philipp. J. Fish. 1(1 & 2):86–126.
360	Ruiz-Ramirez, S., G. Lucano-Ramirez, and J. Mariscal-Romero. 1997. Length-weight relationships of soft-bottom demersal fishes from Jalisco and Colima states, Mexico. Naga ICLARM Q. 20(3/4):62–63.
361	Sadhotomo, B., and S. B. Atmadja. 1985. On the growth of some pelagic fishes in the Java Sea. J. Pen. Perikanan Laut (33):53–60.
362	Saénz-Arroyo, A., C. M. Roberts, J. Torres, M. Cariño-Olvera, and R. R. Enríquez-Andrade. 2005. Rapidly shifting environmental baselines among fishers of the Gulf of California. Proc. R. Soc. Lond Ser. B. Biol. Sci. 272:1957–1962.
363	Saénz-Arroyo, A., M. R. Callum, J. Torre, and M. Cariño-Olvera. 2005. Using fishers' anecdotes, naturalists' observations, and gray literature to reassess marine species at risk: The case of the gulf grouper in the Gulf of California, Mexico. Fish Fish. 6:1211–1133.
364	Sakagawa, G. T., and R. R. Bell. 1980. Swordfish, *Xiphias gladius*. *In* R. S. Shomura (ed.), Summary report of the billfish stock assessment workshop Pacific resources, 5–14 December 1977, p. 40–50. Southwest Fisheries Center, Honolulu Laboratory, HI.
365	Sakuma, K. M., and R. J. Larson. 1995. Distribution of pelagic metamorphic-stage sanddabs *Citharichthys sordidus* and *C.stigmaeus* within areas of upwelling off central California. Fish. Bull. 93(3):516–529.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
366	Sampson, D. B. 1990. A length-structured population model for southern fin whales and a test for density dependence. J. du Conseil pour l'Exploration de la Mer 46:246–268.
367	Sánchez-Cárdenas, R. 2007. Estrategia reproductiva de *Sphoeroides annulatus* (Jenyns 1842) (tetraodontidae) en la costa de Mazatlán, Sinaloa, Mexico. Tesis de Maestría. CICIMAR-IPN.
368	Sandoval-Castillo, J. R. 2002. Caracterizacion genetica de *Lutjanus peru* en el Pacifico Mexicano. Tesis Profesional. Universidad Autónoma de Baja California, La Paz, BCS, Mexico.
369	Santamaría, A., and E. Chávez. 1999. Evaluación de la pesquería de *Lutjanus peru* (Pisces: Lutjanidae) de Guerrero, Mexico. Rev. Biol. Trop. 47(3).
370	Schmitter-Soto, J. J., and J. L. Castro-Aguirre. 1994. Age and growth of three searobins (Pisces: Triglidae) off the western coast of Baja California Sur, Mexico. Rev. Biol. Trop. 42(1/2):271–279.
371	Schneider, M., and R. J. Lavenberg. 1995. Antennariidae. Ranisapos. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 854–857. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
372	Schneider, M. 1995. Chaetodontidae. Peces mariposa. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1000–1003. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
373	Schneider, M. 1995. Ephippidae. Pegualas, curacas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1088–1090. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
374	Schneider, W., and F. Krupp. 1995. Holocentridae. Candiles. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1182–1185. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
375	Schneider, W., and F. Krupp. 1995. Pomacentridae. Castañetas, jaquetas y petacas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1392–1404. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
376	Schreiber, E., and J. Burger. 2002. Biology of marine birds. CRC Press, Boca Raton, LA.
377	Schroeder, R. E. 1982. Length-weight relationships of fishes from Honda Bay, Palawan, Philippines. Fish. Res. J. Philipp. 7(2):50–53.
378	Schultz, L. P. 1933. The age and growth of *Atherinops affinis oregonia* Jordon and Snyder and of other subspecies of baysmelt along the Pacific coast of the United States. Publications in Biology 2:45–102. Univ. Washington, Seattle.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
379	Scotton, L. N., R. E. Smith, N. S. Smith, K. S. Price, and D. P. de Sylva. 1973. Pictorial guide to fish larvae of Delaware Bay: With information and bibliographies useful for the study of fish larvae. Delaware Bay Report Series. Vol. 7. Univ. Delaware, College of Marine Studies, Newark.
380	Secretaría de Pesca. 1994. Desarrollo científico y tecnológico del banco de genoma de tilapia Pages La Secretaría in D. G. d. Acuacultura. (ed). La Secretaría. Secretaría de Pesca, Mexico City, DF.
381	Shiokawa, T. 1988. Managements of ribbon fish resources in the central Japan Sea. Japan Fisheries Resource Conservation Association, Tokyo.
382	Simpfendorfer, C. A., R. B. McAuley, J. Chidlow, and P. Unsworth. 2002. Validated age and growth of the dusky shark, *Carcharhinus obscurus*, from western Australian waters. Mar. Freshw. Res. 53:567–573.
383	Sivasubramanian, K. 1985. Tunas and their fishery in the EEZs of India, Maldives, and Sri Lanka, Colombo, Sri Lanka, Marine Fishery Resources in the Bay of Bengal, RAS/81/051, BOBP/WP/31.
384	Skogsberg, T. 1939. The fishes of the family Sciaenidae (croakers) of California. Calif. Dept. Fish Game Fish Bull. 54.
385	Smith, A., and P. Dalzell. 1993. Fisheries resources and management investigations in Woleai Atoll, Yap State, Federated States of Micronesia. Inshore Fish. Res. Proj., Tech. Doc. South Pacific Commission, Noumea, New Caledonia.
386	Smith, B. D., and G. A. McFarlane. 1990. Growth analysis of Strait of Georgia lingcod by use of length-frequency and length-increment data in combination. Trans. Am. Fish. Soc. 119:802–812.
387	Smith, D. G. 1994. Catalog of type specimens of recent fishes in the National Museum of Natural History, Smithsonian Institution, 6: Anguilliformes, Saccopharyngiformes, and Notacanthiformes (Teleostei: Elopomorpha). Smithson. Contrib. 566.
388	Smith, D. G. 1995. Congridae. Congrios. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1026–1035. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
389	Smith Jr., E. J., and C. V. Paul. 1960. Maturity and fecundity. *In* J.L. Baxter (ed.), A study of the yellowtail *Seriola dorsalis* (Gill). Calif. Dept. Fish Game Fish Bull. 110:46–52.
390	Smith, M. M. 1986. Ostraciidae. *In* M. M. Smith and P. C. Heemstra (eds.), Smiths' sea fishes, p. 890–893. Springer-Verlag, Berlin.
391	Smith, S. E., and N. J. Abramson. 1990. Leopard shark *Triakis semifasciata* distribution, mortality rate, yield, and stock replenishment estimates based on a tagging study in San Francisco Bay. Fish. Bull. 88(2):371–381.
392	Smith, S. E. 1984. Timing of vertebral-band deposition in tetracycline-injected leopard sharks. Trans. Am. Fish. Soc. 113:308–313.
393	Smith, S. W., D. W. Au, and C. Show. 1998. Intrinsic rebound potential of 26 species of Pacific sharks. Mar. Freshw. Res. 49:663–678.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
394	Smith-Vaniz, W. F. 1995. Carangidae. Jureles, pámpanos, cojinúas, zapateros, cocineros, casabes, macarelas, chicharros, jorobados, medregales, pez pilota. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 940–986. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
395	Sommer, C., W. Schneider, and J.-M. Poutiers. 1996. FAO species identification field guide for fishery purposes. The living marine resources of Somalia. FAO, Rome.
396	Sommer, C. 1995. Kyphosidae. Chopas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1195–1200. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
397	Sommer, C. 1995. Pleuronectidae. Platijas, sollas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1381–1385. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
398	Sommer, C. 1995. Sphyraenidae. Barracudas, picudas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1618–1621. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
399	Sousa, M. I., and J. Gjsaeter. 1987. Reproduction, age, and growth of the round scad, *Decapterus macrosoma* (Bleeker 1851) (Carangidae) from Mozambique. Rev. Invest. Pesq. (Maputo) 16:1–18.
400	Sousa, M. I. 1992. Seasonal growth of five commercially important fishes at Sofala Bank, Mozambique. Rev. Invest. Pesq. (Maputo) 21:79–97.
401	Spratt, J. D. 1986. The amazing grunion. California Dept. Fish and Game, Marine Resources Leaflet No. 3.
402	Stein, D. L. 1978. A review of the deepwater Liparidae (Pisces) from the coast of Oregon and adjacent waters. Proc. Calif. Acad. Sci. 127:55.
403	Stephenson, D. K. 1980. Assessment of fishery resources–Gulf of Nicoya, Costa Rica. *In* R. B. Pollnac and J. G. Sutinen (eds.), Small-scale marine resources development, p. 187–203. Univ. Rhode Island, Kingston.
404	Stergiou, K. I., and D. K. Moutopoulos. 2001. A review of length-weight relationships of fishes from Greek marine waters. Naga ICLARM Q. 24(1&2):23–39.
405	Stergiou, K. I., E. D. Christou, D. Georgopoulous, A. Zenetos, and C. Souvermezoglou. 1997. The Hellenic seas: Physics, chemistry, biology, and fisheries. *In* A. D. Ansell, R. N. Gibson, and M. Barnes (eds.), Oceanography and marine biology: An annual review, p. 415–538. University College London Press.
406	Stevens, J. D., and J. M. Lyle. 1989. Biology of three hammerhead sharks (*Eusphyra blochii*, *Sphyrna mokarran,* and *S. lewini*) from northern Australia. Aust. J. Mar. Freshw. Res. 40:129–146.
407	Strategic Assessment Branch. 1990. West coast of North America, coastal and ocean zones, strategic assessment: Data atlas. U.S. Dept. Commer., NOAA, Invertebrate and fish volume. Online at http://westcoastatlas.noaa.gov/welcome.html [accessed 23 May 2011].

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
408	Sun, C.-L., S.-P. Wang, and S.-Z. Yeh. 2000. Age and growth of the swordfish *Xiphias gladius* L. in the waters of Taiwan using anal fin spines. *In* The Third World Fisheries Congress abstracts book, p. 401. Beijing.
409	Tandog-Edralin, D., S. R. Ganaden, and P. Fox. 1988. A comparative study of fish mortality rates in moderately and heavily fished areas of the Philippines. *In* S. C. Venema, J. M. Christensen, and D. Pauly (eds.), Contributions to tropical fisheries biology, p. 468–481. FAO/DANIDA Follow-up training course on fish stock assessment in the tropics, Denmark 1986 and Philippines 1987. FAO Fish. Rep. 389. FAO, Rome.
410	Tandog-Edralin, D. D., E. C. Cortez-Zaragoza, P. Dalzell, and D. Pauly. 1990. Some aspects of the biology and population dynamics of skipjack (*Katsuwonus pelamis*) in Philippine waters. Asian Mar. Biol. 7:15–29.
411	Tapia-García, M., M. C. García-Abad, and G. C. Ladrón de Guevara. 2000. Reproduction, distribution, and abundance of *Bothus constellatus* (Pisces: Bothidae) in the Gulf of Tehuantepec, Mexico. Rev. Biol. Trop. 48(1):205–213.
412	Thiagarajan, R., S. Lazarus, Y. A. Sastry, M. Z. Khan, H. M. Kasim, and K. S. Scariah. 1992. Stock assessment of the ribbonfish, *Trichiurus lepturus* Linnaeus, from the Indian waters. Indian J. Fish. 39(3,4):182–194.
413	Thomas, J. 1968. Management of the white seabass (*Cynoscion nobilis*) in California waters. Calif. Dept. Fish Game Fish Bull. 142.
414	Thomas, R. M. 1985. Growth rate of the pilchard off South West Africa, 1971–1983. Invest. Rep. Sea Fish. Res. Inst. S. Afr. 128-1-41.
415	Thompson, B. A. 1998. Redescription of *Aulopus bajacali* Parin and Kotlyar 1984, comments on its relationships and new distribution records. Ichthyol. Res. 45(1):43–51.
416	Thomson, A. D., L. T. Findley, and A. N. Kerstitch. 2000. Reef fishes of the Sea of Cortez, The rocky shore fishes of the Gulf of California. University of Texas Press, Austin.
417	Thomson, D. A., L. T. Findley, and A. N. Kerstitch. 1979. Reef fishes of the Sea of Cortez, the rocky-shore fishes of the Gulf of California. Wiley & Sons, New York.
418	Thomson, D. A. 1987. Reef fishes of the Sea of Cortez, the rocky-shore fishes of the Gulf of California. University of Arizona Press, Tucson.
419	Thomson, J. M. 1990. Mugilidae. *In* J.C. Quero et al, (eds.), Checklist of the fishes of the eastern tropical Atlantic (CLOFETA). Unesco, Portugal, vol. II:855–859.
420	Thomson, J. M. 1963. Synopsis of biological data on the gray mullet *Mugil cephalus* Linnaeus 1758. Fisheries and Oceanography Fisheries Synopsis No.1(1–8). Commonwealth Scientific and Industrial Research Organization (CSIRO), Clayton South, Victoria, Australia.
421	Thomson, J. M. 1966. The gray mullets: An annual review. Oceanogr. Mar. Biol. 4:301–335.
422	Thomson, J. M. 1963. Synopsis of the biological data on the gray mullet *Mugil cephalus* Linnaeus 1758. Commonwealth Scientific and Industrial Research Organization (CSIRO), Division of Fisheries and Oceanography, Fisheries Synopsis 1, Clayton South, Victoria, Australia.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
423	Tinker, S. W. 1978. Fishes of Hawaii, a handbook of the marine fishes of Hawaii and the central Pacific Ocean. Hawaiian Service Inc., Honolulu.
424	Tokai Laboratory. 1960. Synopsis on the biology of *Sardinops melanostica*. Proceedings of the World Scientific Meeting on the Biology of Sardines and Related Species, Tokyo. 2:213–244.
425	Tokio Wada. 1988. Population dynamics on Japanese sardine, *Sardinops melanostictus*, caught by the domestic purse seine fishery in the waters off the coast of southeastern, Hokkaido. Bull. Hokkaido Reg. Fish. Res. Lab. 52.
426	Torres, C. A. 1996. Aspectos biológico-pesqueros delpargo planero *Lutjanus argentiventris* (Peters 1869) y reconocimiento sobre la pesca artesanal en elMunicipio de Bahía Solano (Chocó-Colombia). Informe Técnico Instituto Nacional de Pesa y Acuicultura INPA, Colombia.
427	Torres Jr., F. S. B. 1991. Tabular data on marine fishes from Southern Africa, Part I. Length-weight relationships. Fishbyte 9(1):50–53.
428	Torres Jr., F. S. B. 1991. Tabular data on marine fishes from Southern Africa, Part II: Growth parameters. Fishbyte 9(2):37–38.
429	Trites, A., and D. Pauly. 1998. Estimating mean body masses of marine mammals from maximum body lengths. Can. J. Zool. 76:886–896.
430	Uchida, R. N. 1986. Berycidae. *In* R. N. Uchida and J. H. Uchiyama (eds.), Fishery atlas of the northwestern Hawaiian Islands, p. 78–79. U.S. Dept. Commer., NOAA Tech. Rep. NMFS-38.
431	Uchiyama, J. H., and R. K. Burch. 1986. Growth of dolphins, *Coryphaena hippurus* and *C. equiselis*, in Hawaiian waters as determined by daily increments on otoliths. Fish. Bull. 84(1):186–191.
432	Uraga, M. R. F. 1986. Edad, crecimiento y estructura poblacional de *Sardinops sagax caerulea* en Bahia Magdalena, durante 1981 a 1984. Master's thesis. Instituto Politecnico Nacional, CICIMAR, Mexico.
433	Valdovinos-Jacobo, L. A. 2006. Edad, crecimiento y mortalidad de la sierra del golfo *Scomberomorus concolor* (Lockington, 1879) en el Golfo de California. Tesis de Maestría. CICIMAR-IPN. La Paz, BCS, Mexico.
434	Valle, S. V., J. P. García-Arteaga, and R. Claro. 1997. Growth parameters of marine fishes in Cuban waters. Naga ICLARM Q. 20(1):34–37.
435	van der Elst, R. P., and F. Adkin (eds.). 1991. Marine linefish: Priority species and research objectives in southern Africa. Oceanogr. Res. Inst., Spec. Publ. No. 1
436	Vasquez-Yeomans, L., and E. Sosa-Cordero. 1992. Culture of grunion *Leuresthes tenuis* (Ayres) larvae to metamorphosis in the laboratory. Cienc. Mar. 18(2):1–18.
437	Venkata Subba Rao, K. 1966. Age and growth of ghol, *Pseudosciaena diacanthus* (Lacepède), in Bombay and Saurashtra waters. Indian J. Fish. 13(1-2):251–292.
438	Victor, B. C. 1986. Duration of the planktonic larval stage of 100 species of Pacific and Atlantic wrasses (family Labridae). Mar. Biol. 90:317–326.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
439	Vojkovich, M. 1992. White seabass. *In* California's living marine resources and their utilization, p. 165–167. California Sea Grant, Sacramento.
440	Wada, T., and M. Kashiwai. 1989. Changes in growth and feeding ground of Japanese sardine with fluctuation in stock abundance. *In* T. Kawasaki, S. Tanaka, Y. Toba, and A. Taniguchi (eds.), Long-term variability of pelagic fish populations and their environment, p. 181–190. Proceedings of the International Symposium, Sendai, Japan, 14–18 November 1989. Pergamon Press (Elsevier), Oxford, UK.
441	Walford, L. 1932. The California barracuda (*Sphyraena argentea*). Calif. Dept. Fish Game Fish Bull. 37.
442	Walker, B. W. 1961. The ecology of the Salton Sea, California, in relation to the sportfishery. Calif. Dept. Fish Game Fish Bull. 113.
443	Waples, R. S., and R. H. Rosenblatt. 1987. Patterns of larval drift in southern California marine shore fishes inferred from allozyme data. Fish. Bull. 85(1):1–11.
444	Warburton, K. 1979. Growth and production of some important species of fish in a Mexican coastal lagoon system. J. Fish Biol. 14:449–464.
445	Warner, R. R. 1975. The reproductive biology of the protogynous hermaphrodite *Pimelmetopon pulchrum* (Pisces: Labridae). Fish. Bull. 73(2):262–283.
446	Wellington, G. M., and D. R. Robertson. 2001. Variation in larval life-history traits among reef fishes across the Isthmus of Panama. Mar. Biol. 138(1):11–22.
447	Whitehead, P. J. P., and R. Rodriguez-Sanchez. 1995. Engraulidae. Anchoas, anchovetas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1067–1087. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
448	Whitehead, P. J. P., and R. Rodriguez-Sanchez. 1995. Pristigasteridae. Arenquillas, sardinetas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1409–1417. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
449	Whitehead, P. J. P., and Y. R. Rodriguez-Sánchez. 1995. Clupeidae. Sardinas, sardinetas, machuelos, sábalos, piquitingas. *In* W. Fischer, F. Krupp, W. Schneider, C. Sommer, K. E. Carpenter, and V. Niem (eds.), Guia FAO para identification de especies para lo fines de la pesca, p. 1015–1025. Pacifico Centro-Oriental. 3 vols. FAO, Rome.
450	Whitehead, P. J. P. 1990. Albulidae. *In* J. C. Quero, J. C. Hureau, C. Karrer, A. Post, and L. Saldanha (eds.), Checklist of the fishes of the eastern tropical Atlantic (CLOFETA), p. 122–124. JNICT, Lisbon; SEI, Paris; and UNESCO, Paris, Vol. 1.
451	Whitehead, P. J. P., G. J. Nelson, and T. Wongratana. 1988. U.N. Food and Agriculture Organization species catalogue, Vol. 7. Clupeoid fishes of the world (Suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies, and wolf-herrings. Part 2–Engraulididae. FAO Fish. Synop. 7(125)Pt. 2. FAO, Rome.

Table A-5 continued. List of references consulted for life history parameters in Table A-4.

ID No.	Source
452	Whitehead, P. J. P. 1985. U.N. Food and Agriculture Organization species catalogue, Vol. 7. Clupeoid fishes of the world (suborder Clupeioidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies, and wolf-herrings. Part 1–Chirocentridae, Clupeidae, and Pristigaste. FAO Fish. Synop. 125(7/1):1–303. FAO, Rome.
453	Wijeyaratne, M. J. S., and H. H. Costa. 1987. Fishery, seasonal abundance, and mortality of gray mullets (Pisces: Mugilidae) in Negombo Lagoon, Sri Lanka. J. Appl. Ichthyol. 3:115–118.
454	Wilson, C. D., and G. W. Boehlert. 1990. The effects of different otolith ageing techniques on estimates of growth and mortality for the splitnose rockfish, *Sebastes diploproa*, and canary rockfish, *S. pinniger*. Calif. Fish. Game 76(3):146–160.
455	Wintner, S. P., and G. Cliff. 1999. Age and growth determination of the white shark, *Carcharodon carcharia*s, from the east coast of South Africa. Fish. Bull. 97(1):153–169.
456	Wintner, S. P., S. F. J. Dudley, N. Kistnasamy, and B. Everett. 2002. Age and growth estimates for the Zambezi shark, *Carcharhinus leucas*, from the east coast of South Africa. Mar. Freshw. Res. 53:557–566.
457	Wintner, S. P. 2000. Preliminary study of vertebral growth rings in the whale shark, *Rhincodon typus*, from the east coast of South Africa. Environ. Biol. Fishes 59:441–451.
458	World Wildlife Fund. 2008. Vaquita–Ecology and habitat. Species factsheets online article. Online at http://wwf.panda.org/index.cfm?uGlobalSearch=vaquita&x=21&y=7 [accessed 28 October 2010].
459	Yoshida, H. O. 1980. Synopsis of biological data on bonitos of the genus *Sarda*. U.S. Dept. Commer., NOAA Tech. Rep. NMFS Circ. 432. FAO Fish. Synop. No. 118, FAO, Rome.
460	Yudin, K. G. 1987. Age, growth, and aspects of the reproductive biology of two sharks, the gray smoothhound *Mustelus californicus* and the brown smoothhound *M. henlei* from central California. Master's thesis. San Francisco State Univ.
461	Yudin, K. G., and G. M. Cailliet. 1990. Age and growth of the gray smoothhound, *Mustelus californicus*, and the brown smoothhound, *M. henlei*, from central California. Copeia 1990(1):191–204.
462	Zapata, F. A., and P. A. Herrón. 2002. Pelagic larval duration and geographic distribution of tropical eastern Pacific snappers (Pisces: Lutjanidae). Mar. Ecol. Prog. Ser. 230:295–300.
463	Zayas-Alvarez, J. A. 1998. Biologia reproductiva del tiburon angel *Squatina californica* (Ayres 1859) (pisces: Squatinidae) en el Golfo de California. Tesis Profesional. Universidad Autónoma de Baja California, La Paz, BCS, Mexico.
464	Zug, G. R., and J. F. Parham. 1996. Age and growth in leatherback turtles, *Dermochelys coriacea* (testudines: Dermochelyidae): A skeletochronological analysis. Chelon. Conserv. Biol. 2:244–249.

Table A-6. Vertebrate growth rate at high prey densities (mg N • d^{-1} • $individual^{-1}$; G in Equation 7).

	Age stanza									
Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
FPS	601	1,283	1,951	3,006	3,652	3,825	4,048	4,108	4,087	4,247
FPL	4.5	13.8	24.1	33.7	41.8	48.5	53.8	57.9	60.9	60.9
FPO	201	285	527	761	801	841	881	920	960	1,001
FVD	4.1	19.5	40.6	66.2	94.5	124	154	183	424	478
FVO	1,500	1611	1,722	1,833	1,944	2,056	2,167	2,278	2,389	2,500
FVV	25.4	30.4	50.1	76.1	78.0	78.7	79.0	79.1	158	158
FVS	83.1	153	181	190	194	195	195	195	390	390
FVT	50.4	52.3	54.9	56.2	58.1	60.4	62.5	65.5	70.1	75.1
FVB	1,000	2,568	4,499	6,284	7802	9,033	10,003	10,754	22,655	23,523
FMN	50	55	60	70	80	90	90	100	100	110
FMM	1,092	1,139	1,151	1,160	1,171	1,190	1,200	1,200	1,210	1,250
FBP	58.3	206	396	599	795	975	1,135	1,273	2,782	2,981
FDS	400	558	646	674	683	686	687	687	1,375	1,375
FDD	824	1,672	2,063	2,563	3,086	3,516	4,001	5,001	6001	7,001
FDB	359	400	421	451	481	511	580	641	700	750
FDC	40.9	465	935	1,416	1,852	2,220	2,517	2,752	5,866	6,142
FDO	25.5	102	145	171	186	194	280	351	404	405
FDE	40.5	393	679	936	1,147	1,314	1,441	1,536	3,214	3,318
FDF	100	1,500	2,500	3,500	4,500	5,500	6,500	7,500	9,500	10,000
FDM	300	322	344	367	389	411	433	455	478	500
FDP	5.7	19.7	38.5	59.8	82	104	125	145	328	362
SHD	1,349	2,961	3,015	3,596	3,925	4,131	4,380	4,502	9,625	5,635
SHC	160	674	1,166	1,642	2,072	2,446	2,764	3,029	6,495	6,854
SHP	81.1	206	251	275	301	325	350	376	451	501
SHB	1.3	3.9	6.7	9.3	11.5	13.2	14.6	15.6	32.9	34.1
SHR	4.0	20.5	35	48.1	59.1	68	75	80.4	169	175
SSK	1.3	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.7	1.8
WDG	1,501	1,881	2,084	2,723	3,191	3,520	3,746	3,898	7,999	8,134
PIN	751	2,097	2,909	3,371	3,617	3,745	3,810	3,843	7,719	7,736
WHB	712,262	898,381	921,615	924,351	924,671	924,709	924,713	924,713	1,849,427	1,849,427
REP	3,700	4,700	7,575	9,824	11,448	12,570	13,327	13,831	28,325	28,760
WHT	120,906	198,973	217,341	249,373	265,877	274,149	278,242	280,255	562,485	563,452
WHS	14,758	39,937	61,579	77,105	87,415	93,999	98,115	100,656	204,429	206,331
SB	279	281	281	281	281	281	281	281	561	561
SP	6,000	8,272	10,108	13,110	15,276	16,774	17,784	18,456	25,798	38,379

Table A-7. Vertebrate ingestion rate (clearance) ($m^3 \cdot mg\ N^{-1} \cdot d^{-1}$; C in Equation 7).

	Age stanza									
Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
FPS	94.8	257	390	481	538	541	546	547	547	547
FPL	1.5	4.6	8	11.2	13.9	15.0	16.7	15.7	17.9	17.5
FPO	20.6	57	105	152	177	195	209	224	241	257
FVD	1.0	3.9	8.1	13.2	18.9	24.8	30.8	36.7	42.4	47.8
FVO	25.4	74	119	154	179	196	207	214	219	222
FVV	4.0	8.7	12.5	12.7	12.9	13.1	13.3	13.5	13.5	13.5
FVS	16	30	36	38	38	38	38	38	38	38
FVT	9.8	10.0	11.6	12	12.2	12.2	12.2	12.2	12.2	12.2
FVB	225	257	450	628	780	903	1,000	1,075	1,133	1,176
FMN	5	25	30	32	34	36	38	40	42	44
FMM	60.8	72.7	80.9	82.6	84.2	86.6	87.7	87.7	88.3	88.3
FBP	20.7	41.1	79.2	120	159	195	227	255	278	298
FDS	32.0	55.8	64.6	67.4	68.3	68.6	68.7	68.7	68.7	68.7
FDD	50.4	167	190	236	291	351	451	500	551	601
FDB	35.9	61.8	70.7	73.3	74.1	74.3	74.3	74.4	74.4	74.4
FDC	11.3	65.5	93.5	142	185	222	252	275	293	307
FDO	8.3	20.3	29.0	34.2	37.2	38.8	39.7	40.1	40.4	40.5
FDE	25.7	39.3	67.9	93.6	115	131	144	154	161	166
FDF	23.2	45.5	171	247	313	367	411	444	470	490
FDM	20.6	22.6	38.2	51.6	93.2	105	114	121	125	128
FDP	1.1	3.9	7.7	12	16.4	20.8	25.1	29.1	32.8	36.2
SHD	94.4	207	270	276	281	285	291	300	306	310
SHC	23.3	67.4	117	164	207	245	276	303	325	343
SHP	23.2	58.7	65.9	80.2	90.6	101	106	111	116	120
SHB	0.3	0.8	1.3	1.9	2.3	2.6	2.9	3.1	3.3	3.4
SHR	1.4	4.1	7.0	9.6	11.8	13.6	15.0	16.1	16.9	17.5
SSK	0.6	0.9	1.2	1.3	1.4	1.4	1.5	1.5	1.6	1.6
WDG	200	211	222	233	244	256	267	278	289	300
PIN	178	419	582	674	723	749	762	769	772	774
WHB	71,226	89,838	92,161	92,435	92,467	92,471	92,471	92,471	92,471	92,471
REP	401	470	757	982	1,145	1,257	1,333	1,383	1,416	1,438
WHT	8,891	19,897	21,734	24,937	26,588	27,415	27,824	28,026	28,124	28,173
WHS	1,476	3,994	6,158	7,710	8,742	9,400	9,812	10,066	10,221	10,317
SB	27.9	28.1	28.1	28.1	28.1	28.1	28.1	28.1	28.1	28.1
SP	601	800	1,011	1,311	1,528	1,677	1,778	1,846	1,890	1,919

Table A-8. Spawning parameters. Spawn date is day of year when spawning begins (day 1 is January 1), spawn window is number of days spawning lasts, and settling window is number of days until recruitment into age-class 1.

Functional group	**Code**	**Spawn date**	**Spawn window**	**Settling window**	**Source**
Gulf coney	FBP	150	14	11	CEDO unpubl. data
Extranjero	FDB	59	60	15	CEDO unpubl. data
Leopard grouper	FDC	120	14	15	Default assumption
Gulf grouper	FDD	120	14	15	Default assumption
Amarillo snapper	FDE	120	14	15	Default assumption
Barred pargo	FDF	150	120	11	CEDO unpubl. data
Groupers and snappers	FDM	120	30	15	Default assumption
Drums and croakers	FDO	59	92	18	R. Loaiza-Villanueva[a,b]
Grunts	FDP	120	60	15	Default assumption
Herbivorous fish	FDS	90	90	19	Default assumption
Large reef fish	FMM	151	90	22	COBI unpubl. data[c]
Small reef fish	FMN	90	90	25	Default assumption
Small demersal fish	FPL	90	90	13	Default assumption
Pacific angel shark	FPS	59	122	60	DeCraene and Fink 2004
Small migratory sharks	FPO	120	90	45	COBI unpubl. data[d]
Large pelagic sharks	FVB	59	122	15	R. Loaiza-Villanueva[a,e]
Guitarfish	FVD	105	75	15	COBI unpubl. data[f]
Skates, rays, sharks	FVO	90	60	60	COBI unpubl. data[g]
Flatfish	FVS	30	120	19	COBI unpubl. data[h]
Mojarra	FVT	120	60	15	Default assumption
Scorpionfish	FVV	120	60	23	Default assumption
Lanternfish and deep	SHB	90	60	15	Default assumption
Totoaba	SHC	120	30	15	Default assumption
Large pelagics	SHD	90	60	26	Default assumption
Mackerel	SHP	120	14	15	Default assumption
Hake	SHR	120	14	15	Default assumption
Small pelagics	SSK	90	30	18	Default assumption
Mysticeti	WHB	120	365	90	Default assumption
Odontocetae	WHT	90	330	90	Default assumption
Orca	WHS	120	330	60	Default assumption
Vaquita	WDG	120	330	30	WWF 2008
Pinnipeds	PIN	120	330	90	Default assumption
Oceanic sea turtles	SP	120	30	30	Default assumption
Reef associated turtles	REP	120	30	23	Default assumption
Sea birds	SB	120	60	11	Default assumption
Adult blue crab	CEP	1	365	—	COBI unpubl. data
Adult blue shrimp	PWN	59	92	—	CEDO unpubl. data

[a]R. Loaiza-Villanueva, CEDO, Puerto Peñasco, Sonora, Mexico. Pers. commun., September 2008.
[b]Based on *Cynoscion othonopterus* and *Micropogonias megalops*.
[c]Based on Balistidae.
[d]Based on *Mustelus lunulatus* and *Rhizoprionodon longurio*.
[e]Based on *Rhizoprionodon* spp.
[f]Based on *Rhinobatos productus*.
[g]Based on Rajidae.
[h]Based on Paralichthidae and Pleuronectidae.

Table A-9. Availability matrix. Predator is in boldface, followed by prey species.

Scallops/penshells	
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Refractory detritus	2.0E-01
Labile detritus	1.0E-01
Sed. refractory detritus	1.1E-02
Sm. phytoplankton	1.0E-02
Sm. zooplankton	1.0E-02
Lg. phytoplankton	6.9E-03
Lg. zooplankton	2.0E-05
Penaeid shrimp	
Pelagic bacteria	3.0E-01
Benthic bacteria	3.0E-01
Labile detritus	5.4E-02
Carrion detritus	1.1E-02
Sed. refractory detritus	1.1E-02
Sed. carrion detritus	1.1E-02
Lg. phytoplankton	6.9E-03
Sed. labile detritus	5.4E-03
Sm. phytoplankton	1.0E-03
Sm. zooplankton	1.0E-03
Refractory detritus	1.0E-03
Carn. macrobenthos	3.5E-04
Lg. zooplankton	4.1E-05
Meiobenthos	3.1E-05
Macroalgae	3.0E-06
Microphytobenthos	7.6E-08
Sea cucumbers	
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Sed. carrion detritus	5.0E-01
Sed. labile detritus	3.3E-01
Refractory detritus	5.0E-02
Macroalgae	1.7E-05
Seagrass	1.0E-05
Sessile invertebrates	
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Refractory detritus	5.0E-02
Sm. phytoplankton	1.0E-02
Sm. zooplankton	1.0E-02
Lg. phytoplankton	6.9E-03
Sed. refractory detritus	2.1E-03
Lg. zooplankton	2.0E-05
Crabs/lobsters	
Penaeid shrimp	5.0E-01
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Refractory detritus	1.0E-01
Sed. carrion detritus	2.1E-02
Sed. labile detritus	1.1E-02
Sed. refractory detritus	1.1E-02
Ad. blue crab	1.0E-02
Carn. macrobenthos	1.0E-02
Sm. zooplankton	1.0E-02
Meiobenthos	5.0E-03
Bivalves	5.0E-03
Lg. phytoplankton	3.4E-03
Squid	1.6E-03
Sea cucumbers	1.0E-03
Scallops/penshells	1.0E-03
Jellyfish	1.0E-03
Snails	5.0E-04
Herb. echinoderms	2.4E-04
Crabs/lobsters	2.2E-04
Microphytobenthos	1.0E-04
Seagrass	2.2E-05
Lg. zooplankton	1.2E-05
Sm. phytoplankton	1.0E-05
Macroalgae	1.5E-06
Sessile invertebrates	4.9E-07
Herb. echinoderms	
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Scallops/penshells	5.0E-02
Macroalgae	1.0E-03
Microphytobenthos	1.0E-03
Refractory detritus	1.0E-03
Seagrass	2.5E-04
Carn. macrobenthos	
Scallops/penshells	2.5E-01
Crabs/lobsters	5.0E-02
Sed. carrion detritus	4.5E-02
Ad. blue crab	4.4E-02
Meiobenthos	1.0E-02
J. blue crab	5.0E-03
Sed. labile detritus	4.5E-03
Herb. echinoderms	1.0E-03
Bivalves	1.0E-03
Microphytobenthos	1.0E-03
Refractory detritus	1.0E-03
Sea cucumbers	5.0E-04
Snails	5.0E-04
Carn. macrobenthos	1.0E-04
Sessile invertebrates	5.1E-06
Meiobenthos	
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Labile detritus	2.0E-01
Refractory detritus	2.0E-01
Scallops/penshells	1.0E-01
Sed. carrion detritus	4.5E-02
Sed. labile detritus	2.3E-02
Carrion detritus	1.0E-03
Snails	5.0E-04
Meiobenthos	2.3E-04
Microphytobenthos	1.1E-06
Bivalves	
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Labile detritus	5.0E-01
Sm. zooplankton	2.0E-01
Sed. refractory detritus	2.0E-01
Lg. phytoplankton	1.3E-01
Sm. phytoplankton	1.0E-01
Sed. labile detritus	1.0E-01
Microphytobenthos	2.0E-03
Refractory detritus	1.0E-03
Lg. zooplankton	1.0E-05
Snails	
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Sed. carrion detritus	6.4E-02
Sed. labile detritus	3.2E-02
Sed. refractory detritus	3.2E-02
Refractory detritus	1.0E-03
Macroalgae	3.0E-06
Microphytobenthos	6.8E-07
Ad. blue crab	
Sed. refractory detritus	1.0E-01
Sed. carrion detritus	1.0E-01
Scallops/penshells	5.0E-02
Labile detritus	5.0E-02
Sed. labile detritus	3.9E-02
Jellyfish	1.0E-02
Snails	5.1E-03
Refractory detritus	1.0E-03
Carrion detritus	1.0E-03
Sessile invertebrates	3.1E-04
Crabs/lobsters	1.0E-04
Bivalves	1.0E-04
Carn. macrobenthos	9.6E-05
Sea cucumbers	5.0E-05
Meiobenthos	1.1E-05
Ad. sm. demersal fish	1.0E-05
Macroalgae	2.3E-06

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

J. blue crab	
Sed. refractory detritus	1.0E-01
Sed. carrion detritus	1.0E-01
Labile detritus	5.0E-02
Sed. labile detritus	3.9E-02
Jellyfish	1.0E-02
Snails	5.1E-03
J. blue crab	1.0E-03
Refractory detritus	1.0E-03
Carrion detritus	1.0E-03
Sessile invertebrates	3.1E-04
Meiobenthos	1.9E-04
Crabs/lobsters	1.0E-04
Bivalves	1.0E-04
Carn. macrobenthos	9.6E-05
Sea cucumbers	5.0E-05
Ad. sm. demersal fish	1.0E-05
Macroalgae	2.3E-06
J. Gulf coney	
J. Gulf coney	1.0E-01
J. drums, croakers	1.0E-01
Ad. scorpionfish	1.0E-01
Ad. drums, croakers	1.0E-01
Carn. macrobenthos	1.0E-01
Meiobenthos	1.0E-01
Penaeid shrimp	1.0E-01
Ad. flatfish	5.0E-02
Crabs/lobsters	5.0E-02
J. scorpionfish	1.0E-02
J. flatfish	1.0E-02
J. sm. reef fish	1.0E-02
Ad. sm. reef fish	1.0E-02
Jellyfish	1.0E-02
Refractory detritus	1.0E-02
J. groupers/snappers	1.0E-03
J. grunts	1.0E-03
Sea cucumbers	5.0E-04
Ad. blue crab	1.3E-04
J. sm. demersal fish	1.0E-04
Ad. sm. demersal fish	1.0E-04
Lg. zooplankton	1.0E-04
Ad. grunts	1.0E-05
Ad. Gulf coney	
Penaeid shrimp	2.0E-01
Ad. blue shrimp	1.0E-01
J. blue crab	4.0E-02
J. scorpionfish	1.0E-02
J. flatfish	1.0E-02
J. sm. reef fish	1.0E-02
J. Gulf coney	1.0E-02
J. grunts	1.0E-02
Ad. scorpionfish	1.0E-02
Ad. flatfish	1.0E-02
Ad. Gulf coney	1.0E-02
Ad. groupers/snappers	1.0E-02
Ad. grunts	1.0E-02
Ad. sm. pelagics	1.0E-02
Crabs/lobsters	1.0E-02
Jellyfish	1.0E-02
Lg. phytoplankton	1.0E-02
Sm. zooplankton	1.0E-02
Refractory detritus	1.0E-02
Ad. skates, rays	1.0E-03
Ad. sm. reef fish	1.0E-03
Sea cucumbers	1.0E-03
Carn. macrobenthos	1.0E-03
Meiobenthos	1.0E-03
Bivalves	1.0E-03
Ad. blue crab	6.3E-04
J. Sm. demersal fish	1.0E-04
Ad. Sm. demersal fish	1.0E-04
Lg. zooplankton	1.0E-04
J. extranjero	
J. lanternfish/deep	5.0E-02
Ad. lanternfish/deep	5.0E-02
Carn. macrobenthos	1.0E-02
J. sm. reef fish	8.0E-03
Ad. sm. reef fish	8.0E-03
J. flatfish	5.0E-03
J. hake	5.0E-03
Ad. hake	5.0E-03
J. sm. demersal fish	1.0E-03
J. Gulf coney	1.0E-03
Ad. sm. demersal fish	1.0E-03
Ad. flatfish	1.0E-03
Sea cucumbers	1.0E-03
Meiobenthos	1.0E-03
J. grunts	8.0E-04
Ad. grunts	8.0E-04
J. sm. pelagics	5.0E-04
Ad. sm. pelagics	5.0E-04
Crabs/lobsters	9.8E-05
Squid	3.5E-05
Snails	1.9E-05
Ad. blue shrimp	2.7E-07
Bivalves	1.8E-07
Lg. zooplankton	1.2E-07
Penaeid shrimp	1.7E-08
Ad. extranjero	
J. blue shrimp	2.0E-02
Jellyfish	1.0E-02
J. hake	1.0E-04
Ad. hake	1.0E-04
Crabs/lobsters	9.8E-05
J. sm. reef fish	5.0E-05
J. Gulf coney	5.0E-05
J. grunts	5.0E-05
J. lanternfish/deep	5.0E-05
Ad. sm. demersal fish	5.0E-05
Ad. flatfish	5.0E-05
Ad. sm. reef fish	5.0E-05
Ad. Gulf coney	5.0E-05
Ad. grunts	5.0E-05
Ad. Lanternfish/deep	5.0E-05
Lg. zooplankton	3.3E-05
J. flatfish	3.0E-05
Snails	1.9E-05
J. sm. demersal fish	1.0E-05
Sea cucumbers	1.0E-05
Carn. macrobenthos	1.0E-05
Ad. blue shrimp	1.6E-06
Meiobenthos	1.0E-06
J. sm. pelagics	1.0E-06
Ad. sm. pelagics	1.0E-06
Bivalves	1.8E-07
Penaeid shrimp	1.0E-07
J. leopard grouper	
J. mojarra	5.0E-02
Ad. mojarra	5.0E-02
Crabs/lobsters	5.0E-02
Penaeid shrimp	5.0E-02
Jellyfish	2.0E-02
J. lg. reef fish	1.0E-02
J. sm. reef fish	1.0E-02
Ad. sm. reef fish	1.0E-02
Refractory detritus	1.0E-02
J. sm. demersal fish	5.0E-03
J. sm. pelagics	5.0E-03
Ad. flatfish	5.0E-03
J. Scorpionfish	2.0E-03
J. flatfish	2.0E-03
Ad. lg. reef fish	1.0E-03
Squid	7.0E-04
J. hake	5.0E-04

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

Ad. hake	5.0E-04	Ad. mojarra	5.0E-02	Ad. sm. demersal fish	1.0E-04
Ad. sm. pelagics	5.0E-04	Ad. sm. reef fish	4.0E-02	Crabs/lobsters	4.1E-05
J. Gulf coney	1.0E-04	J. sm. demersal fish	1.0E-02	Ad. blue shrimp	6.8E-06
J. grunts	1.0E-04	J. flatfish	1.0E-02	Penaeid shrimp	5.6E-07
Ad. Gulf coney	1.0E-04	J. lg. reef fish	1.0E-02	**J. amarillo snapper**	
Sea cucumbers	1.0E-04	J. sm. reef fish	1.0E-02	Sm. zooplankton	3.0E-01
Carn. macrobenthos	1.0E-04	J. extranjero	1.0E-02	J. sm. reef fish	1.0E-01
Meiobenthos	1.0E-04	Ad. sm. pelagics	1.0E-02	Ad. sm. reef fish	1.0E-01
Ad. sm. demersal fish	1.0E-05	Carn. macrobenthos	1.0E-02	J. flatfish	6.0E-02
Ad. grunts	1.0E-05	Squid	1.0E-02	J. Gulf grouper	3.0E-02
Lg. zooplankton	1.0E-05	J. sm. pelagics	8.0E-03	Ad. blue shrimp	2.0E-02
Ad. blue shrimp	3.9E-06	J. hake	5.0E-03	Jellyfish	2.0E-02
Herb. echinoderms	1.0E-07	J. Gulf coney	1.0E-03	Meiobenthos	2.0E-02
Ad. leopard grouper		J. grunts	1.0E-03	J. sm. demersal fish	1.0E-02
J. mojarra	1.0E-01	Ad. flatfish	1.0E-03	J. groupers/snappers	1.0E-02
Ad. mojarra	1.0E-01	Ad. lg. reef fish	1.0E-03	Ad. sm. demersal fish	1.0E-02
J. scorpionfish	5.0E-02	Ad. hake	1.0E-03	Ad. flatfish	1.0E-02
J. sm. pelagics	5.0E-02	Sea cucumbers	1.0E-03	Ad. Gulf coney	1.0E-02
Ad. scorpionfish	5.0E-02	Meiobenthos	1.0E-03	J. hake	5.0E-03
Ad. lg. reef fish	5.0E-02	Ad. sm. demersal fish	1.0E-05	J. sm. pelagics	5.0E-03
Ad. sm. pelagics	5.0E-02	Lg. zooplankton	1.0E-05	Ad. hake	5.0E-03
Jellyfish	2.0E-02	**Ad. Gulf grouper**		Ad. sm. pelagics	5.0E-03
J. lg. reef fish	1.0E-02	J. mojarra	1.0E-01	Scallops/penshells	1.0E-03
J. grunts	1.0E-02	Ad. mojarra	1.0E-01	Herb. echinoderms	1.0E-03
J. blue shrimp	1.0E-02	Ad. sm. reef fish	7.0E-02	J. guitarfish	1.0E-03
Ad. flatfish	1.0E-02	J. sm. pelagics	5.0E-02	J. grunts	1.0E-03
Ad. Gulf coney	1.0E-02	Ad. lg. reef fish	5.0E-02	J. extranjero	1.0E-03
Ad. hake	1.0E-02	Ad. sm. pelagics	5.0E-02	Ad. guitarfish	1.0E-03
Carrion detritus	1.0E-02	Jellyfish	2.0E-02	Penaeid shrimp	1.0E-03
J. hake	2.6E-03	J. lg. reef fish	1.0E-02	Squid	1.0E-03
J. sm. demersal fish	1.0E-03	J. blue shrimp	1.0E-02	Crabs/lobsters	1.0E-03
J. Gulf coney	1.0E-03	Ad. leopard grouper	1.0E-02	J. Gulf coney	1.0E-04
Meiobenthos	1.0E-03	Ad. hake	1.0E-02	Ad. grunts	1.0E-04
J. flatfish	1.0E-04	Sea cucumbers	1.0E-02	Carn. macrobenthos	7.1E-05
J. groupers/snappers	1.0E-04	J. flatfish	5.0E-03	Sea cucumbers	5.0E-05
Ad. sm. demersal fish	1.0E-04	Ad. flatfish	5.0E-03	Lg. zooplankton	1.0E-05
Carn. macrobenthos	1.0E-04	J. sm. reef fish	2.0E-03	**Ad. amarillo snapper**	
Crabs/lobsters	7.5E-05	J. sm. demersal fish	1.0E-03	Ad. sm. reef fish	4.0E-02
Sea cucumbers	5.0E-05	J. Gulf coney	1.0E-03	J. blue shrimp	1.0E-02
Ad. blue shrimp	3.1E-05	J. groupers/snappers	1.0E-03	J. sm. reef fish	1.0E-03
J. sm. reef fish	1.0E-05	J. grunts	1.0E-03	J. extranjero	1.0E-03
Ad. sm. reef fish	1.0E-05	J. extranjero	1.0E-03	Squid	7.0E-04
Penaeid shrimp	2.5E-06	J. leopard grouper	1.0E-03	Crabs/lobsters	1.4E-04
J. Gulf grouper		J. drums/croakers	1.0E-03	Ad. blue shrimp	1.0E-04
Sm. zooplankton	3.0E-01	J. hake	1.0E-03	Sea cucumbers	5.0E-05
Ad. blue shrimp	7.0E-02	Ad. Gulf coney	1.0E-03	Carn. macrobenthos	3.8E-05
Crabs/lobsters	7.0E-02	Ad. grunts	1.0E-03	Meiobenthos	2.3E-05
Penaeid shrimp	7.0E-02	Carn. macrobenthos	1.0E-03	Lg. zooplankton	1.0E-05
J. mojarra	5.0E-02	Meiobenthos	1.0E-03	J. sm. demersal fish	1.0E-05

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

J. Gulf coney	1.0E-05	Ad. lg. reef fish	1.0E-04	Sea cucumbers	5.0E-05
J. grunts	1.0E-05	Crabs/lobsters	4.5E-05	J. flatfish	1.0E-05
Ad. sm. demersal fish	1.0E-05	Sea cucumbers	3.2E-05	J. sm. reef fish	1.0E-05
Ad. Gulf coney	1.0E-05	Carn. macrobenthos	2.2E-05	J. amarillo snapper	1.0E-05
Ad. grunts	1.0E-05	Lg. zooplankton	1.0E-05	Ad. flatfish	1.0E-05
Penaeid shrimp	1.5E-06	J. Gulf coney	1.0E-05	Ad. sm. reef fish	1.0E-05
J. barred pargo		J. grunts	1.0E-05	Ad. amarillo snapper	1.0E-05
Sm. zooplankton	3.0E-01	Ad. Gulf coney	1.0E-05	Ad. extranjero	1.0E-05
J. sm. demersal fish	5.0E-02	Ad. grunts	1.0E-05	Lg. zooplankton	1.0E-05
J. extranjero	5.0E-02	Meiobenthos	3.1E-06	Sm. phytoplankton	2.2E-06
Ad. sm. reef fish	5.0E-02	Penaeid shrimp	2.1E-07	J. herbivorous fish	1.0E-06
Squid	3.5E-02	**J. groupers/snappers**		Ad. herbivorous fish	1.0E-06
Jellyfish	2.0E-02	Sm. zooplankton	3.0E-01	**Ad. groupers/snappers**	
Ad. sm. demersal fish	1.3E-02	Refractory detritus	2.0E-01	Refractory detritus	2.0E-01
Ad. blue shrimp	1.0E-02	Ad. barred pargo	3.0E-02	Sm. zooplankton	1.5E-01
J. sm. reef fish	1.0E-02	Jellyfish	2.0E-02	J. blue shrimp	5.0E-02
J. Gulf coney	1.0E-02	J. skates, rays	1.0E-02	Jellyfish	2.0E-02
J. grunts	1.0E-02	J. Gulf grouper	1.0E-02	J. Gulf grouper	1.0E-02
Crabs/lobsters	1.0E-02	J. reef turtles	1.0E-02	J. reef turtles	1.0E-02
Meiobenthos	1.0E-02	Ad. Gulf grouper	1.0E-02	Ad. Gulf grouper	1.0E-02
Pelagic bacteria	1.0E-02	Ad. reef turtles	1.0E-02	Ad. reef turtles	1.0E-02
Benthic bacteria	1.0E-02	Squid	7.0E-03	Ad. herbivorous fish	5.0E-03
J. groupers/snappers	1.0E-03	J. sm. pelagics	1.4E-03	J. mojarra	1.0E-03
Ad. groupers/snappers	1.0E-03	J. mojarra	1.0E-03	J. skates, rays	1.0E-03
Ad. sm. pelagics	1.0E-03	J. Gulf coney	1.0E-03	J. Gulf coney	1.0E-03
Penaeid shrimp	1.0E-03	J. extranjero	1.0E-03	J. drums/croakers	1.0E-03
J. scorpionfish	1.0E-04	J. drums/croakers	1.0E-03	Ad. mojarra	1.0E-03
J. lg. reef fish	1.0E-04	Ad. mojarra	1.0E-03	Ad. skates, rays	1.0E-03
Ad. lg. reef fish	1.0E-04	Ad. skates, rays	1.0E-03	Ad. Gulf coney	1.0E-03
Sea cucumbers	9.3E-05	Ad. Gulf coney	1.0E-03	Ad. leopard grouper	1.0E-03
Carn. macrobenthos	6.5E-05	Ad. leopard grouper	1.0E-03	Ad. drums/croakers	1.0E-03
Lg. zooplankton	1.0E-05	Ad. drums/croakers	1.0E-03	Ad. barred pargo	1.0E-03
Ad. barred pargo		Ad. sm. pelagics	6.3E-04	Ad. sm. pelagics	2.8E-04
J. sm. pelagics	5.0E-02	Labile detritus	4.1E-04	Crabs/lobsters	1.9E-04
Ad. sm. reef fish	5.0E-02	Carrion detritus	1.6E-04	Squid	1.2E-04
Ad. sm. pelagics	5.0E-02	Carn. macrobenthos	1.0E-04	Labile detritus	1.0E-04
Squid	3.5E-02	Penaeid shrimp	1.0E-04	J. guitarfish	1.0E-04
J. sm. reef fish	1.0E-02	Ad. blue shrimp	1.0E-04	J. groupers/snappers	1.0E-04
J. groupers/snappers	1.0E-02	J. guitarfish	1.0E-04	J. grunts	1.0E-04
J. blue shrimp	1.0E-02	J. groupers/snappers	1.0E-04	J. leopard grouper	1.0E-04
Ad. groupers/snappers	1.0E-02	J. grunts	1.0E-04	J. barred pargo	1.0E-04
Ad. sm. demersal fish	2.9E-03	J. leopard grouper	1.0E-04	J. totoaba	1.0E-04
J. sm. demersal fish	1.7E-03	J. barred pargo	1.0E-04	Ad. buitarfish	1.0E-04
J. extranjero	1.0E-03	J. totoaba	1.0E-04	Ad. groupers/snappers	1.0E-04
J. hake	1.0E-03	Ad. guitarfish	1.0E-04	Ad. grunts	1.0E-04
Ad. hake	1.0E-03	Ad. groupers/snappers	1.0E-04	J. sm. pelagics	5.9E-05
Ad. blue shrimp	1.0E-04	Ad. grunts	1.0E-04	Sea cucumbers	5.0E-05
J. scorpionfish	1.0E-04	Crabs/lobsters	1.0E-04	Carrion detritus	4.2E-05
J. lg. reef fish	1.0E-04	Meiobenthos	1.0E-04	Ad. blue shrimp	3.8E-05

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

Carn. macrobenthos	2.0E-05	Bivalves	1.3E-06	Ad. sm. pelagics	1.0E-02
J. flatfish	1.0E-05	Seagrass	1.0E-07	Sea cucumbers	5.0E-03
J. sm. reef fish	1.0E-05	**Ad. drums/croakers**		Carrion detritus	4.2E-03
J. amarillo snapper	1.0E-05	J. blue shrimp	5.0E-02	Squid	2.6E-03
J. extranjero	1.0E-05	Sm. zooplankton	5.0E-02	J. Gulf coney	1.0E-03
Ad. flatfish	1.0E-05	Refractory detritus	5.0E-02	Ad. Gulf coney	1.0E-03
Ad. sm. reef fish	1.0E-05	Ad. sm. pelagics	3.0E-02	Meiobenthos	1.0E-03
Ad. amarillo snapper	1.0E-05	J. sm. pelagics	2.0E-02	Crabs/lobsters	1.0E-04
Ad. extranjero	1.0E-05	Ad. sm. demersal fish	2.0E-02	Herb. echinoderms	1.0E-05
Meiobenthos	5.7E-06	J. sm. demersal fish	1.0E-02	Lg. zooplankton	1.0E-05
J. herbivorous fish	1.0E-06	J. flatfish	1.0E-02	**Ad. grunts**	
Sm. phytoplankton	5.5E-07	Ad. flatfish	1.0E-02	Refractory detritus	5.0E-02
Penaeid shrimp	3.9E-07	Ad. Gulf coney	1.0E-02	J. sm. demersal fish	1.0E-02
Lg. zooplankton	7.7E-09	Jellyfish	1.0E-03	J. sm. reef fish	1.0E-02
J. drums/croakers		J. sm. reef fish	1.0E-03	J. sm. pelagics	1.0E-02
Sm. zooplankton	1.5E-01	J. Gulf coney	1.0E-03	Ad. sm. demersal fish	1.0E-02
Refractory detritus	5.0E-02	Ad. sm. reef fish	1.0E-03	Ad. sm. reef fish	1.0E-02
Ad. sm. demersal fish	3.0E-02	Ad. herbivorous fish	1.0E-03	Ad. sm. pelagics	1.0E-02
J. flatfish	2.0E-02	Ad. barred pargo	1.0E-03	Herb. echinoderms	1.0E-02
J. sm. pelagics	2.0E-02	J. hake	5.0E-04	Sea cucumbers	5.0E-03
Ad. flatfish	2.0E-02	Ad. hake	5.0E-04	Labile detritus	3.1E-03
Ad. sm. pelagics	2.0E-02	Snails	1.5E-04	Crabs/lobsters	2.4E-03
J. sm. demersal fish	1.0E-03	Microphytobenthos	1.0E-04	Carrion detritus	1.2E-03
J. sm. reef fish	1.0E-03	Labile detritus	1.0E-04	J. Gulf coney	1.0E-03
J. Gulf coney	1.0E-03	Carrion detritus	1.0E-04	Ad. Gulf coney	1.0E-03
Ad. sm. reef fish	1.0E-03	J. herbivorous fish	1.0E-04	Meiobenthos	1.0E-03
Ad. Gulf coney	1.0E-03	J. barred pargo	1.0E-04	**J. herbivorous fish**	
Squid	2.8E-04	J. totoaba	1.0E-04	Lg. phytoplankton	2.0E-01
Snails	1.4E-04	Ad. lanternfish/deep	1.0E-04	Microphytobenthos	1.5E-01
J. herbivorous fish	1.0E-04	Ad. blue shrimp	6.6E-05	Penaeid shrimp	1.0E-01
J. barred pargo	1.0E-04	Sea cucumbers	5.0E-05	Sm. zooplankton	1.0E-01
J. totoaba	1.0E-04	Sessile invertebrates	1.6E-05	Seagrass	1.0E-01
J. hake	1.0E-04	Meiobenthos	1.0E-05	Refractory detritus	5.0E-02
Ad. herbivorous fish	1.0E-04	Penaeid shrimp	8.8E-06	Macroalgae	1.0E-02
Ad. barred pargo	1.0E-04	Herb. echinoderms	6.5E-06	Herb. echinoderms	2.0E-04
Ad. hake	1.0E-04	Crabs/lobsters	6.1E-06	Crabs/lobsters	1.0E-04
Crabs/lobsters	1.0E-04	Carn. macrobenthos	2.3E-06	Meiobenthos	1.0E-04
Microphytobenthos	1.0E-04	Macroalgae	2.0E-06	Labile detritus	7.6E-05
Labile detritus	1.0E-04	Bivalves	1.5E-06	Sea cucumbers	5.0E-05
Carrion detritus	1.0E-04	Lg. zooplankton	8.8E-07	Carrion detritus	3.0E-05
Sea cucumbers	5.0E-05	Seagrass	1.1E-07	Snails	1.7E-05
Sessile invertebrates	1.4E-05	**J. Grunts**		J. Gulf coney	1.0E-05
Lg. zooplankton	1.0E-05	Labile detritus	1.0E-01	Lg. zooplankton	1.0E-05
Meiobenthos	1.0E-05	Refractory detritus	5.0E-02	Sessile invertebrates	1.7E-06
Ad. blue shrimp	8.3E-06	J. sm. demersal fish	1.0E-02	Jellyfish	1.7E-06
Penaeid shrimp	7.8E-06	J. sm. reef fish	1.0E-02	Ad. blue shrimp	1.5E-06
Herb. echinoderms	5.7E-06	J. sm. pelagics	1.0E-02	Carn. macrobenthos	2.5E-07
Carn. macrobenthos	2.0E-06	Ad. sm. demersal fish	1.0E-02	Bivalves	1.6E-07
Macroalgae	1.7E-06	Ad. sm. reef fish	1.0E-02	J. sm. demersal fish	1.0E-07

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

Ad. herbivorous fish	
Microphytobenthos	8.0E-02
J. blue shrimp	5.0E-02
Seagrass	5.0E-02
Sm. zooplankton	5.0E-02
Refractory detritus	5.0E-02
Macroalgae	1.0E-02
Lg. phytoplankton	1.0E-03
Sed. refractory detritus	1.0E-03
Labile detritus	1.1E-04
Ad. herbivorous fish	1.0E-04
Sea cucumbers	5.0E-05
Carrion detritus	4.4E-05
Snails	2.4E-05
Ad. blue shrimp	1.0E-05
J. Gulf coney	1.0E-05
Ad. Gulf coney	1.0E-05
Sessile invertebrates	2.5E-06
Jellyfish	2.4E-06
Herb. echinoderms	1.0E-06
Crabs/lobsters	9.6E-07
Carn. macrobenthos	3.5E-07
Bivalves	2.3E-07
Meiobenthos	1.6E-07
Penaeid shrimp	1.1E-07
Lg. zooplankton	6.9E-08
J. lg. reef fish	
J. Gulf grouper	1.0E-01
Ad. sm. reef fish	1.0E-01
Ad. herbivorous fish	1.0E-01
Sm. zooplankton	5.0E-02
Ad. leopard grouper	3.0E-02
Ad. drums/croakers	3.0E-02
J. leopard grouper	2.0E-02
J. sm. reef fish	1.0E-02
J. extranjero	1.0E-02
J. barred pargo	1.0E-02
Ad. Gulf grouper	1.0E-02
Refractory detritus	1.0E-02
Ad. flatfish	5.0E-03
Ad. sm. demersal fish	1.5E-03
J. sm. demersal fish	1.0E-03
J. flatfish	1.0E-03
J. mojarra	1.0E-03
J. herbivorous fish	1.0E-03
J. grunts	1.0E-03
Ad. mojarra	1.0E-03
Ad. grunts	1.0E-03
Sed. refractory detritus	1.0E-03
J. sm. pelagics	7.3E-04
J. hake	7.2E-04
Ad. sm. pelagics	3.2E-04
Ad. hake	1.3E-04
J. amarillo snapper	1.0E-04
J. drums/croakers	1.0E-04
J. totoaba	1.0E-04
Ad. amarillo snapper	1.0E-04
Sessile invertebrates	3.3E-05
Squid	2.6E-05
J. Gulf coney	1.0E-05
Ad. Gulf coney	1.0E-05
Ad. extranjero	1.0E-05
Ad. barred pargo	1.0E-05
Bivalves	5.6E-06
Snails	5.3E-06
Crabs/lobsters	5.3E-06
Labile detritus	1.2E-06
Ad. blue shrimp	8.4E-07
Jellyfish	5.4E-07
Carrion detritus	4.8E-07
Sea cucumbers	3.1E-07
Herb. echinoderms	2.2E-07
Carn. macrobenthos	7.8E-08
Penaeid shrimp	4.7E-08
Meiobenthos	3.5E-08
Lg. zooplankton	3.1E-08
Seagrass	3.9E-09
J. groupers/snappers	1.0E-10
Ad. groupers/snappers	1.0E-10
Ad. lg. reef fish	
J. blue shrimp	5.0E-02
Sm. zooplankton	3.0E-02
Refractory detritus	2.0E-02
J. extranjero	1.0E-02
J. barred pargo	1.0E-02
Ad. sm. reef fish	2.2E-03
Ad. mojarra	2.0E-03
J. mojarra	1.0E-03
J. Gulf grouper	1.0E-03
Ad. Gulf grouper	1.0E-03
J. grunts	5.0E-04
Ad. sm. demersal fish	5.0E-04
J. sm. reef fish	3.8E-04
Jellyfish	1.0E-04
J. sm. demersal fish	1.0E-04
J. flatfish	1.0E-04
J. amarillo snapper	1.0E-04
J. leopard grouper	1.0E-04
Ad. flatfish	1.0E-04
Ad. amarillo snapper	1.0E-04
Ad. grunts	1.0E-04
Ad. leopard grouper	1.0E-04
Ad. drums/croakers	1.0E-04
Sed. refractory detritus	1.0E-04
Sessile invertebrates	8.4E-05
J. sm. pelagics	6.7E-05
J. hake	6.6E-05
Squid	5.9E-05
Bivalves	1.4E-05
Snails	1.4E-05
Crabs/lobsters	1.4E-05
J. Gulf coney	1.0E-05
J. herbivorous fish	1.0E-05
J. drums/croakers	1.0E-05
Ad. Gulf coney	1.0E-05
Ad. herbivorous fish	1.0E-05
Ad. extranjero	1.0E-05
Ad. barred pargo	1.0E-05
Ad. hake	1.0E-05
Ad. sm. pelagics	1.0E-05
Labile detritus	3.1E-06
Carrion detritus	1.2E-06
Ad. blue shrimp	1.2E-06
Sea cucumbers	7.9E-07
Herb. echinoderms	5.7E-07
Carn. macrobenthos	2.0E-07
Penaeid shrimp	1.2E-07
Meiobenthos	9.0E-08
Lg. zooplankton	7.9E-08
Seagrass	1.0E-08
J. groupers/snappers	1.0E-10
Ad. groupers/snappers	1.0E-10
J. sm. reef fish	
Sm. zooplankton	3.0E-01
Labile detritus	2.0E-01
Refractory detritus	2.0E-01
Scallops/penshells	1.2E-01
Penaeid shrimp	1.0E-01
Carn. macrobenthos	1.0E-01
Pelagic bacteria	5.0E-02
Sed. refractory detritus	5.0E-02
Carrion detritus	5.0E-02
J. Gulf grouper	1.0E-02
J. sm. pelagics	1.0E-02
Ad. sm. reef fish	1.0E-02
Ad. amarillo snapper	1.0E-02
Ad. leopard grouper	1.0E-02

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

Ad. sm. pelagics	1.0E-02
Jellyfish	1.0E-02
J. sm. reef fish	5.3E-03
J. sm. demersal fish	5.0E-03
Snails	3.0E-03
Sessile invertebrates	2.1E-03
J. grunts	1.0E-03
Ad. sm. demersal fish	1.0E-03
Ad. grunts	1.0E-03
Squid	2.9E-04
Sea cucumbers	2.0E-04
J. flatfish	1.0E-04
J. groupers/snappers	1.0E-04
J. leopard grouper	1.0E-04
J. drums/croakers	1.0E-04
J. hake	1.0E-04
Ad. hake	1.0E-04
Sm. phytoplankton	4.3E-05
Herb. echinoderms	3.1E-05
Crabs/lobsters	3.0E-05
Bivalves	2.1E-05
Meiobenthos	1.5E-05
J. Gulf coney	1.0E-05
J. amarillo snapper	1.0E-05
J. extranjero	1.0E-05
J. barred pargo	1.0E-05
Ad. barred pargo	1.0E-05
Microphytobenthos	9.5E-06
Macroalgae	1.9E-06
J. herbivorous fish	1.0E-06
Ad. herbivorous fish	1.0E-06
Seagrass	1.1E-07
Lg. zooplankton	1.0E-07
Ad. sm. reef fish	
Sm. zooplankton	2.5E-01
Refractory detritus	2.0E-01
Carn. macrobenthos	1.0E-01
Penaeid shrimp	1.0E-01
J. blue shrimp	5.0E-02
Pelagic bacteria	5.0E-02
Ad. amarillo snapper	1.0E-02
Jellyfish	1.0E-02
Sed. refractory detritus	1.0E-02
Ad. sm. reef fish	1.3E-03
Snails	1.2E-03
Ad. sm. demersal fish	1.0E-03
Sessile invertebrates	8.4E-04
J. mackerel	5.0E-04
J. sm. demersal fish	4.0E-04
J. sm. reef fish	2.2E-04
Sea cucumbers	2.0E-04
J. Gulf grouper	1.0E-04
J. grunts	1.0E-04
J. leopard grouper	1.0E-04
J. drums/croakers	1.0E-04
J. hake	1.0E-04
J. sm. pelagics	1.0E-04
Ad. Gulf grouper	1.0E-04
Ad. groupers/snappers	1.0E-04
Ad. grunts	1.0E-04
Ad. leopard grouper	1.0E-04
Ad. drums/croakers	1.0E-04
Ad. hake	1.0E-04
Ad. sm. pelagics	1.0E-04
Sm. phytoplankton	1.7E-05
Labile detritus	1.3E-05
Squid	1.3E-05
Herb. echinoderms	1.2E-05
Crabs/lobsters	1.2E-05
J. Gulf coney	1.0E-05
J. amarillo snapper	1.0E-05
J. groupers/snappers	1.0E-05
J. extranjero	1.0E-05
J. barred pargo	1.0E-05
Ad. Gulf coney	1.0E-05
Ad. extranjero	1.0E-05
Ad. barred pargo	1.0E-05
Bivalves	8.4E-06
Carrion detritus	5.3E-06
Ad. blue shrimp	5.0E-06
Microphytobenthos	3.7E-06
J. herbivorous fish	1.0E-06
Ad. herbivorous fish	1.0E-06
Macroalgae	7.5E-07
Lg. zooplankton	1.0E-07
Meiobenthos	5.8E-08
Seagrass	4.3E-08
J. sm. demersal fish	
Sm. zooplankton	3.5E-01
Refractory detritus	2.0E-01
Sed. refractory detritus	1.6E-01
Sed. carrion detritus	1.0E-01
Snails	2.2E-02
Sed. labile detritus	1.6E-02
J. flatfish	1.0E-02
J. sm. reef fish	1.0E-02
J. drums/croakers	1.0E-02
Ad. scorpionfish	1.0E-02
Ad. flatfish	1.0E-02
Ad. sm. reef fish	1.0E-02
Ad. drums/croakers	1.0E-02
Penaeid shrimp	1.0E-02
Sm. phytoplankton	1.0E-02
Bivalves	2.1E-03
Squid	2.1E-03
Labile detritus	2.0E-03
Sessile invertebrates	1.0E-03
Ad. blue crab	1.0E-03
J. sm. demersal fish	1.0E-03
J. scorpionfish	1.0E-03
J. mojarra	1.0E-03
J. grunts	1.0E-03
Ad. sm. demersal fish	1.0E-03
Ad. mojarra	1.0E-03
Ad. grunts	1.0E-03
Meiobenthos	1.0E-03
Carn. macrobenthos	2.2E-04
Sea cucumbers	2.0E-04
Ad. blue shrimp	1.5E-04
J. groupers/snappers	1.0E-04
Crabs/lobsters	1.0E-04
Microphytobenthos	9.5E-05
Carrion detritus	6.7E-05
Lg. zooplankton	3.3E-05
Macroalgae	1.9E-05
J. Gulf coney	1.0E-05
Ad. Gulf coney	1.0E-05
Seagrass	1.1E-06
Ad. sm. demersal fish	
Carn. macrobenthos	2.0E-01
Refractory detritus	2.0E-01
Sed. refractory detritus	2.0E-01
J. sm. reef fish	1.0E-01
J. blue crab	5.0E-02
J. blue shrimp	5.0E-02
Sm. zooplankton	5.0E-02
Sed. carrion detritus	4.0E-02
Sed. labile detritus	2.0E-02
J. flatfish	1.0E-02
Ad. scorpionfish	1.0E-02
Ad. flatfish	1.0E-02
Ad. sm. reef fish	1.0E-02
Penaeid shrimp	1.0E-02
Snails	9.2E-03
Ad. blue shrimp	1.1E-03
Sessile invertebrates	1.0E-03
Meiobenthos	1.0E-03

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

J. sm. demersal fish	1.0E-03	J. mackerel	1.0E-05	Ad. amarillo snapper	1.0E-05
J. scorpionfish	1.0E-03	Ad. mackerel	1.0E-05	Ad. herbivorous fish	1.0E-05
J. mojarra	1.0E-03	Scallops/penshells	9.7E-06	Ad. lg. pelagics	1.0E-05
J. grunts	1.0E-03	Meiobenthos	8.4E-06	Ad. sm. pelagics	1.0E-05
Ad. sm. demersal fish	1.0E-03	Sessile invertebrates	6.4E-06	Meiobenthos	2.9E-06
Ad. mojarra	1.0E-03	Ad. blue shrimp	5.3E-06	Sessile invertebrates	2.2E-06
Ad. grunts	1.0E-03	Herb. echinoderms	4.5E-06	Herb. echinoderms	1.6E-06
Bivalves	8.8E-04	Penaeid shrimp	4.3E-06	Penaeid shrimp	1.5E-06
Ad. blue crab	2.7E-04	Bivalves	1.9E-06	J. herbivorous fish	1.0E-06
Sm. phytoplankton	1.8E-04	Macroalgae	1.5E-06	Bivalves	6.6E-07
Squid	1.3E-04	Sea cucumbers	1.3E-06	Macroalgae	5.3E-07
Crabs/lobsters	1.0E-04	Microphytobenthos	1.1E-06	Sea cucumbers	4.6E-07
J. groupers/snappers	1.0E-04	J. amarillo snapper	1.0E-06	Microphytobenthos	3.7E-07
Ad. groupers/snappers	1.0E-04	J. herbivorous fish	1.0E-06	Carn. macrobenthos	6.4E-08
Sea cucumbers	1.0E-04	Ad. herbivorous fish	1.0E-06	Seagrass	1.1E-08
Labile detritus	6.9E-05	Lg. zooplankton	4.8E-08	**J. Pacific angel shark**	
Microphytobenthos	3.9E-05	Seagrass	3.1E-08	Meiobenthos	2.0E-01
Carrion detritus	2.8E-05	**Ad. sm. mig. sharks**		Labile detritus	1.5E-01
J. Gulf coney	1.0E-05	Labile detritus	5.0E-02	J. flatfish	1.0E-01
Ad. Gulf coney	1.0E-05	Scallops/penshells	4.0E-02	J. sm. reef fish	1.0E-01
Macroalgae	7.8E-06	J. blue crab	1.0E-02	Ad. Gulf grouper	1.0E-01
Seagrass	4.5E-07	J. blue shrimp	1.0E-02	Penaeid shrimp	1.0E-01
Lg. zooplankton	3.5E-07	Jellyfish	1.0E-02	Carrion detritus	1.0E-01
J. sm. mig. sharks		Refractory detritus	1.0E-02	Ad. flatfish	8.0E-02
Labile detritus	2.0E-01	Carrion detritus	1.0E-02	Ad. sm. reef fish	4.0E-02
J. sm. reef fish	1.4E-02	J. lanternfish/deep	2.0E-04	Squid	3.5E-02
Refractory detritus	1.0E-02	Ad. lanternfish/deep	2.0E-04	Herb. echinoderms	2.0E-02
Carrion detritus	1.0E-02	Crabs/lobsters	1.9E-04	J. sm. demersal fish	1.0E-02
Ad. sm. reef fish	7.5E-03	Ad. sm. reef fish	1.6E-04	J. scorpionfish	1.0E-02
Ad. sm. pelagics	2.5E-03	Ad. blue crab	1.6E-04	J. herbivorous fish	1.0E-02
Ad. lanternfish/deep	2.1E-03	J. sm. demersal fish	1.0E-04	Carn. macrobenthos	1.0E-02
J. sm. demersal fish	2.0E-03	J. flatfish	1.0E-04	Ad. sm. demersal fish	9.9E-03
Ad. sm. demersal fish	2.0E-03	Ad. sm. demersal fish	1.0E-04	Microphytobenthos	1.0E-03
J. lanternfish/deep	1.2E-03	Ad. flatfish	1.0E-04	Refractory detritus	1.0E-03
J. flatfish	1.0E-03	J. mackerel	5.0E-05	J. Gulf grouper	1.0E-04
J. lg. pelagics	1.0E-03	Ad. mackerel	5.0E-05	Macroalgae	1.0E-04
Ad. flatfish	1.0E-03	Ad. blue shrimp	3.7E-05	Seagrass	2.0E-08
Ad. amarillo snapper	1.0E-03	J. hake	3.0E-05	Lg. zooplankton	1.1E-08
Ad. lg. pelagics	1.0E-03	Ad. hake	3.0E-05	**Ad. Pacific angel shark**	
Crabs/lobsters	5.4E-04	J. sm. reef fish	2.8E-05	Ad. flatfish	5.0E-03
J. scorpionfish	1.0E-04	Snails	1.6E-05	Meiobenthos	5.0E-03
J. hake	1.0E-04	Squid	1.3E-05	Penaeid shrimp	5.0E-03
J. sm. pelagics	1.0E-04	J. scorpionfish	1.0E-05	Ad. sm. demersal fish	2.0E-03
Ad. scorpionfish	1.0E-04	J. Gulf grouper	1.0E-05	J. sm. demersal fish	1.0E-03
Ad. hake	1.0E-04	J. amarillo snapper	1.0E-05	J. flatfish	1.0E-03
Squid	6.5E-05	J. lg. pelagics	1.0E-05	Ad. sm. reef fish	1.0E-03
Snails	4.6E-05	J. sm. pelagics	1.0E-05	Labile detritus	1.0E-03
Ad. blue crab	2.3E-05	Ad. scorpionfish	1.0E-05	Refractory detritus	1.0E-03
Carn. macrobenthos	1.9E-05	Ad. Gulf grouper	1.0E-05	Squid	1.6E-04

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

J. sm. reef fish	1.0E-04
Lg. zooplankton	1.0E-05
Carrion detritus	1.0E-05
Microphytobenthos	1.2E-06
Macroalgae	2.3E-07
Seagrass	1.3E-08
J. lg. pelagic sharks	
J. Odontocetae	3.0E-01
J. skates, rays	1.0E-01
J. pinnipeds	1.0E-01
Ad. skates, rays	1.0E-01
Ad. Gulf coney	1.0E-01
Ad. leopard grouper	1.0E-01
Labile detritus	1.0E-01
J. guitarfish	5.0E-02
J. lg. reef fish	5.0E-02
J. leopard grouper	5.0E-02
J. sm. pelagics	5.0E-02
J. reef turtles	5.0E-02
Ad. guitarfish	5.0E-02
Ad. herbivorous fish	5.0E-02
Ad. groupers/snappers	5.0E-02
Ad. lanternfish/deep	5.0E-02
Ad. sm. pelagics	5.0E-02
Ad. pinnipeds	5.0E-02
Ad. reef turtles	5.0E-02
J. flatfish	3.0E-02
J. mojarra	2.0E-02
J. lanternfish/deep	2.0E-02
Ad. flatfish	2.0E-02
Ad. mojarra	2.0E-02
Ad. Odontocetae	1.5E-02
J. lg. pelagic sharks	1.0E-02
J. sm. reef fish	1.0E-02
J. grunts	1.0E-02
J. extranjero	1.0E-02
J. drums/croakers	1.0E-02
Ad. lg. pelagic sharks	1.0E-02
Ad. lg. reef fish	1.0E-02
Ad. Gulf grouper	1.0E-02
Ad. grunts	1.0E-02
Ad. extranjero	1.0E-02
Ad. mackerel	1.0E-02
J. mackerel	9.0E-03
Ad. sm. reef fish	5.0E-03
Ad. drums/croakers	5.0E-03
Jellyfish	1.0E-03
J. sm. mig. sharks	1.0E-03
J. groupers/snappers	1.0E-03
J. lg. pelagics	1.0E-03
J. hake	1.0E-03
Ad. hake	1.0E-03
Refractory detritus	1.0E-03
Ad. lg. pelagics	5.0E-04
J. sm. demersal fish	1.0E-04
J. herbivorous fish	1.0E-04
J. oceanic turtles	1.0E-04
Ad. sm. demersal fish	1.0E-04
Ad. oceanic turtles	1.0E-04
Scallops/penshells	1.0E-04
Squid	2.8E-05
Crabs/lobsters	1.0E-05
J. sea birds	1.0E-05
Ad. sm. mig. sharks	1.0E-05
Penaeid shrimp	1.0E-05
Ad. blue crab	1.6E-07
Ad. sea birds	1.0E-07
Ad. blue shrimp	3.2E-08
Snails	2.1E-08
Macroalgae	1.9E-08
Carn. macrobenthos	6.6E-09
Lg. zooplankton	4.0E-09
Meiobenthos	2.9E-09
Sessile invertebrates	2.2E-09
Herb. echinoderms	1.6E-09
Sea cucumbers	1.3E-09
Bivalves	6.0E-10
Seagrass	2.8E-10
Ad. lg. pelagic sharks	
J. guitarfish	1.5E-01
J. pinnipeds	1.5E-01
Ad. guitarfish	1.5E-01
Ad. pinnipeds	1.3E-01
Ad. lanternfish/deep	1.0E-01
Labile detritus	1.0E-01
J. skates, rays	8.0E-02
Ad. skates, rays	8.0E-02
Ad. grunts	8.0E-02
J. reef turtles	7.4E-02
J. lanternfish/deep	6.0E-02
J. mojarra	5.0E-02
J. Gulf coney	5.0E-02
J. grunts	5.0E-02
J. sm. pelagics	5.0E-02
J. Odontocetae	5.0E-02
J. blue crab	5.0E-02
J. blue shrimp	5.0E-02
Ad. mojarra	5.0E-02
Ad. Gulf coney	5.0E-02
Ad. sm. pelagics	5.0E-02
Ad. reef turtles	4.8E-02
J. flatfish	2.0E-02
J. drums/croakers	2.0E-02
Ad. flatfish	2.0E-02
Ad. drums/croakers	2.0E-02
Ad. mackerel	2.0E-02
J. lg. pelagic sharks	1.0E-02
J. lg. reef fish	1.0E-02
J. sm. reef fish	1.0E-02
J. extranjero	1.0E-02
J. mackerel	1.0E-02
Ad. lg. pelagic sharks	1.0E-02
Ad. lg. reef fish	1.0E-02
Ad. extranjero	1.0E-02
Ad. oceanic turtles	1.0E-02
Ad. Mysticeti	1.0E-02
Ad. orca	1.0E-02
Ad. sm. reef fish	5.0E-03
Ad. Odontocetae	4.9E-03
J. lg. pelagics	2.0E-03
J. oceanic turtles	2.0E-03
J. Mysticeti	2.0E-03
J. orca	2.0E-03
Ad. lg. pelagics	2.0E-03
Jellyfish	1.0E-03
J. groupers/snappers	1.0E-03
J. hake	1.0E-03
J. sea birds	1.0E-03
Ad. groupers/snappers	1.0E-03
Ad. hake	1.0E-03
Ad. sea birds	1.0E-03
Refractory detritus	1.0E-03
J. vaquita	2.0E-04
Scallops/penshells	1.0E-04
J. sm. demersal fish	1.0E-04
J. sm. mig. sharks	1.0E-04
Ad. sm. demersal fish	1.0E-04
Ad. sm. mig. sharks	1.0E-04
Crabs/lobsters	1.0E-05
Penaeid shrimp	1.0E-05
Squid	8.0E-06
Ad. blue crab	9.8E-07
Ad. blue shrimp	1.9E-07
Snails	6.6E-09
Macroalgae	5.8E-09
Carn. macrobenthos	1.8E-09
Meiobenthos	1.2E-09

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

Sessile invertebrates	6.0E-10	J. mojarra	1.0E-03	Ad. flatfish	1.9E-03
Herb. echinoderms	6.0E-10	J. skates, rays	1.0E-03	J. mojarra	1.5E-03
Sea cucumbers	3.0E-10	J. lanternfish/deep	1.0E-03	J. flatfish	1.0E-03
Seagrass	6.0E-11	Ad. mojarra	1.0E-03	Ad. lg. reef fish	1.0E-03
J. guitarfish		Ad. skates, rays	1.0E-03	Ad. amarillo snapper	1.0E-03
Labile detritus	1.0E-01	Ad. lg. reef fish	1.0E-03	Ad. lanternfish/deep	1.0E-03
J. lg. reef fish	5.0E-02	Ad. amarillo snapper	1.0E-03	Refractory detritus	1.0E-03
Crabs/lobsters	1.2E-02	Ad. lanternfish/deep	1.0E-03	Ad. sm. reef fish	5.9E-04
Jellyfish	1.0E-03	Refractory detritus	1.0E-03	Ad. sm. pelagics	2.6E-04
Refractory detritus	1.0E-03	Ad. sm. pelagics	7.1E-04	J. grunts	1.0E-04
Squid	2.5E-04	Ad. sm. demersal fish	1.9E-04	J. lanternfish/deep	1.0E-04
Bivalves	2.2E-04	Crabs/lobsters	1.2E-04	J. sm. pelagics	1.0E-04
J. sm. demersal fish	1.0E-04	J. sm. demersal fish	1.0E-04	Ad. scorpionfish	1.0E-04
J. sm. reef fish	1.0E-04	J. scorpionfish	1.0E-04	Ad. drums/croakers	1.0E-04
Ad. sm. demersal fish	1.0E-04	J. grunts	1.0E-04	J. sm. reef fish	9.9E-05
Ad. sm. reef fish	1.0E-04	J. drums/croakers	1.0E-04	Ad. sm. demersal fish	7.1E-05
Carn. macrobenthos	5.8E-05	Ad. drums /croakers	1.0E-04	Crabs/lobsters	6.7E-05
Meiobenthos	4.1E-05	Bivalves	2.4E-05	J. sm. demersal fish	4.1E-05
Ad. blue shrimp	2.7E-05	Snails	1.6E-05	Bivalves	1.3E-05
Penaeid shrimp	1.4E-05	Meiobenthos	1.5E-05	J. herbivorous fish	1.0E-05
Lg. zooplankton	4.5E-07	Squid	1.1E-05	J. groupers/snappers	1.0E-05
Ad. guitarfish		J. herbivorous fish	1.0E-05	J. lg. pelagics	1.0E-05
Labile detritus	1.0E-01	J. groupers/snappers	1.0E-05	Ad. herbivorous fish	1.0E-05
J. blue shrimp	5.0E-02	J. lg. pelagics	1.0E-05	Ad. groupers/snappers	1.0E-05
Jellyfish	1.0E-03	Ad. herbivorous fish	1.0E-05	Ad. lg. pelagics	1.0E-05
Refractory detritus	1.0E-03	Ad. groupers/snappers	1.0E-05	Snails	9.1E-06
Crabs/lobsters	9.2E-04	Ad. lg. pelagics	1.0E-05	Meiobenthos	8.7E-06
Ad. blue shrimp	1.1E-04	Carn. macrobenthos	9.4E-06	Carn. macrobenthos	5.3E-06
J. sm. demersal fish	1.0E-04	Sessile invertebrates	6.6E-07	Squid	7.8E-07
J. sm. reef fish	1.0E-04	Jellyfish	6.5E-07	Sessile invertebrates	3.7E-07
Ad. sm. demersal fish	1.0E-04	Herb. echinoderms	4.8E-07	Jellyfish	3.7E-07
Ad. sm. reef fish	1.0E-04	Microphytobenthos	4.1E-07	Ad. blue shrimp	3.1E-07
Bivalves	1.7E-05	Macroalgae	8.2E-08	Herb. echinoderms	2.7E-07
Carn. macrobenthos	4.5E-06	Lg. zooplankton	6.0E-08	Microphytobenthos	2.3E-07
Meiobenthos	3.1E-06	Ad. blue shrimp	4.5E-08	Macroalgae	4.6E-08
Penaeid shrimp	1.1E-06	Penaeid shrimp	5.7E-09	Lg. zooplankton	3.1E-08
J. skates, rays		Seagrass	4.7E-09	Penaeid shrimp	3.2E-09
Labile detritus	1.0E-01	**Ad. skates, rays**		Seagrass	2.7E-09
J. lg. reef fish	5.0E-02	Labile detritus	1.0E-01	**J. flatfish**	
Sm. zooplankton	5.0E-02	J. lg. reef fish	5.0E-02	Scallops/penshells	1.0E-01
J. flatfish	3.1E-02	J. blue shrimp	5.0E-02	Meiobenthos	1.0E-01
J. Gulf grouper	1.0E-02	Sm. zooplankton	5.0E-02	Labile detritus	1.0E-01
Ad. Gulf grouper	1.0E-02	Ad. skates, rays	3.2E-02	Herb. echinoderms	1.0E-02
Ad. grunts	1.0E-02	J. skates, rays	1.3E-02	J. sm. demersal fish	1.0E-02
Ad. flatfish	5.1E-03	Ad. Gulf grouper	1.0E-02	Refractory detritus	1.0E-02
Ad. scorpionfish	4.1E-03	Ad. grunts	1.0E-02	Ad. sm. demersal fish	3.6E-03
Ad. sm. reef fish	3.6E-03	J. scorpionfish	9.1E-03	J. flatfish	2.1E-03
J. sm. reef fish	3.3E-03	J. drums/croakers	3.7E-03	J. guitarfish	1.0E-03
J. sm. pelagics	1.6E-03	Ad. mojarra	3.0E-03	J. sm. pelagics	1.0E-03

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

Ad. guitarfish	1.0E-03
Ad. flatfish	3.5E-04
Squid	1.4E-04
J. lanternfish/deep	1.0E-04
J. hake	1.0E-04
Ad. lanternfish/deep	1.0E-04
Ad. hake	1.0E-04
Ad. sm. pelagics	1.0E-04
Ad. blue shrimp	7.7E-05
Penaeid shrimp	3.3E-05
Crabs/lobsters	2.3E-05
J. sm. reef fish	1.0E-05
Ad. sm. reef fish	1.0E-05
Lg. zooplankton	1.0E-05
Ad. flatfish	
Labile detritus	1.0E-01
J. blue shrimp	5.0E-02
J. flatfish	1.4E-02
Refractory detritus	1.0E-02
Ad. sm. demersal fish	2.6E-03
J. sm. demersal fish	1.5E-03
J. guitarfish	1.0E-03
Ad. guitarfish	1.0E-03
Ad. blue shrimp	6.2E-04
Ad. flatfish	2.6E-04
J. lanternfish/deep	1.0E-04
J. hake	1.0E-04
J. sm. pelagics	1.0E-04
Ad. lanternfish/deep	1.0E-04
Ad. hake	1.0E-04
Ad. sm. pelagics	1.0E-04
Penaeid shrimp	6.8E-05
Crabs/lobsters	4.8E-05
J. sm. reef fish	1.0E-05
Ad. sm. reef fish	1.0E-05
J. mojarra	
Sm. zooplankton	3.0E-01
Labile detritus	2.0E-01
Snails	1.0E-01
Refractory detritus	5.0E-02
Crabs/lobsters	1.8E-03
Microphytobenthos	1.5E-03
J. scorpionfish	1.0E-03
Ad. scorpionfish	1.0E-03
Penaeid shrimp	1.0E-03
Carn. macrobenthos	7.0E-04
Squid	7.0E-04
Bivalves	4.8E-04
Meiobenthos	4.2E-04
Sea cucumbers	2.8E-04
Herb. echinoderms	1.1E-04
J. sm. demersal fish	1.0E-04
J. sm. reef fish	1.0E-04
Ad. sm. reef fish	1.0E-04
Macroalgae	1.0E-04
Jellyfish	9.3E-05
Ad. blue shrimp	7.1E-05
J. hake	1.0E-05
Ad. sm. demersal fish	1.0E-05
Ad. hake	1.0E-05
Lg. zooplankton	1.0E-05
Carrion detritus	1.0E-05
Seagrass	4.8E-06
Ad. mojarra	
Labile detritus	1.0E-01
Snails	6.0E-02
Sm. zooplankton	5.0E-02
Refractory detritus	5.0E-02
Carrion detritus	3.5E-02
Squid	1.4E-02
J. blue shrimp	1.0E-02
Crabs/lobsters	4.1E-03
Microphytobenthos	3.3E-03
Carn. macrobenthos	1.6E-03
Bivalves	1.1E-03
Penaeid shrimp	1.0E-03
Meiobenthos	9.3E-04
Sea cucumbers	6.2E-04
Ad. blue shrimp	5.7E-04
Herb. echinoderms	2.5E-04
Jellyfish	2.1E-04
J. sm. demersal fish	1.0E-04
J. sm. reef fish	1.0E-04
Ad. sm. reef fish	1.0E-04
Macroalgae	6.5E-05
Seagrass	1.1E-05
J. scorpionfish	1.0E-05
J. hake	1.0E-05
Ad. sm. demersal fish	1.0E-05
Ad. scorpionfish	1.0E-05
Ad. hake	1.0E-05
Lg. zooplankton	1.0E-05
J. scorpionfish	
Sm. zooplankton	4.0E-01
Labile detritus	1.5E-01
J. flatfish	1.0E-02
J. sm. reef fish	1.0E-02
Ad. flatfish	1.0E-02
Ad. sm. reef fish	1.0E-02
Snails	4.0E-03
Ad. blue shrimp	3.0E-03
J. sm. demersal fish	2.0E-03
Ad. sm. demersal fish	2.0E-03
Crabs/lobsters	2.0E-03
Meiobenthos	1.0E-03
Squid	1.0E-03
Refractory detritus	1.0E-03
Carn. macrobenthos	1.0E-04
Bivalves	1.0E-04
Penaeid shrimp	1.0E-04
Lg. zooplankton	1.0E-05
Ad. scorpionfish	
Sm. zooplankton	1.0E-01
Labile detritus	1.0E-01
J. blue shrimp	5.0E-02
J. flatfish	1.0E-02
Ad. flatfish	1.0E-02
Crabs/lobsters	2.9E-03
Snails	1.9E-03
Squid	1.0E-03
J. sm. demersal fish	1.0E-03
J. sm. reef fish	1.0E-03
Ad. sm. demersal fish	1.0E-03
Ad. sm. reef fish	1.0E-03
Refractory detritus	1.0E-03
Ad. blue shrimp	2.4E-04
Carn. macrobenthos	8.3E-05
Lg. zooplankton	6.2E-05
Bivalves	4.6E-05
Meiobenthos	7.6E-06
Penaeid shrimp	2.5E-06
J. pinnipeds	
Carn. macrobenthos	2.0E-01
Ad. flatfish	1.0E-01
Ad. hake	1.0E-01
Crabs/lobsters	1.0E-01
J. flatfish	5.0E-02
Ad. sm. demersal fish	2.0E-02
J. sm. pelagics	1.0E-02
Ad. sm. pelagics	1.0E-02
Ad. mackerel	5.0E-03
Squid	1.4E-03
J. mojarra	1.0E-03
Ad. mojarra	1.0E-03
J. sm. demersal fish	1.0E-04
J. grunts	1.0E-04
J. drums/croakers	1.0E-04

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

J. lanternfish/deep	1.0E-04	Macroalgae	1.5E-07	Microphytobenthos	1.0E-03
Ad. grunts	1.0E-04	**J. blue shrimp**		Ad. blue shrimp	1.0E-03
Ad. drums/croakers	1.0E-04	Pelagic bacteria	5.0E-01	Penaeid shrimp	1.0E-03
Ad. lanternfish/deep	1.0E-04	Benthic bacteria	1.0E-01	Lg. phytoplankton	5.0E-06
J. groupers/snappers	1.0E-05	Labile detritus	1.3E-02	**J. Sea birds**	
J. totoaba	1.0E-05	Sed. refractory detritus	5.1E-03	J. sm. demersal fish	1.0E-03
Ad. groupers/snapper	1.0E-05	Sm. phytoplankton	4.3E-03	J. sm. pelagics	1.0E-03
Ad. totoaba	1.0E-05	Lg. phytoplankton	3.5E-03	Ad. sm. demersal fish	1.0E-03
Ad. pinnipeds		Carrion detritus	2.7E-03	Ad. lg. pelagics	1.0E-03
Ad. hake	1.0E-01	Sed. carrion detritus	2.7E-03	Ad. sm. pelagics	1.0E-03
Sm. zooplankton	1.0E-01	Sed. labile detritus	1.3E-03	Carrion detritus	1.0E-03
Carn. macrobenthos	5.0E-02	Microphytobenthos	1.0E-03	Squid	3.5E-04
Ad. sm. pelagics	1.0E-02	Refractory detritus	1.0E-03	J. lanternfish/deep	1.0E-04
Ad. mackerel	5.0E-03	Sm. zooplankton	1.3E-04	J. lg. pelagics	1.0E-04
Ad. flatfish	2.3E-03	Carn. macrobenthos	1.7E-05	Ad. lanternfish/deep	1.0E-04
J. flatfish	1.3E-03	Lg. zooplankton	1.0E-05	Carn. macrobenthos	1.0E-04
Ad. sm. demersal fish	1.1E-03	Meiobenthos	3.9E-06	Sm. zooplankton	1.0E-04
J. mojarra	1.0E-03	Macroalgae	1.5E-07	Bivalves	4.5E-05
Ad. mojarra	1.0E-03	**J. reef turtles**		Lg. zooplankton	1.3E-05
Squid	7.0E-04	Sm. zooplankton	2.0E-01	**Ad. sea birds**	
J. sm. demersal fish	6.4E-04	Carn. macrobenthos	1.2E-01	Ad. sm. pelagics	1.0E-01
J. sm. pelagics	4.3E-04	Meiobenthos	1.0E-01	Carrion detritus	5.7E-02
J. grunts	1.0E-04	Jellyfish	8.0E-02	J. lanternfish/deep	1.0E-02
J. drums/croakers	1.0E-04	Bivalves	5.0E-02	J. hake	1.0E-02
J. lanternfish/deep	1.0E-04	Scallops/penshells	5.0E-02	Ad. lanternfish/deep	1.0E-02
Ad. grunts	1.0E-04	Refractory detritus	5.0E-02	Ad. hake	1.0E-02
Ad. drums/croakers	1.0E-04	Macroalgae	2.0E-02	Carn. macrobenthos	1.0E-02
Ad. lanternfish/deep	1.0E-04	Sessile invertebrates	1.0E-02	Squid	1.2E-03
J. groupers/snappers	1.0E-05	Seagrass	1.0E-02	J. mackerel	1.0E-03
J. totoaba	1.0E-05	Sea cucumbers	1.0E-02	Scallops/penshells	1.0E-03
Ad. groupers/snapper	1.0E-05	Sed. refractory detritus	1.4E-03	Sm. zooplankton	3.0E-04
Ad. totoaba	1.0E-05	Microphytobenthos	1.0E-03	J. lg. pelagics	1.0E-04
Crabs/lobsters	1.2E-07	Ad. blue shrimp	1.0E-03	J. sm. pelagics	1.0E-04
Ad. blue shrimp		Lg. zooplankton	1.0E-03	Ad. lg. pelagics	5.0E-05
Pelagic bacteria	5.0E-01	Lg. phytoplankton	3.8E-05	Bivalves	4.5E-05
Sm. zooplankton	1.0E-01	**Ad. reef turtles**		Lg. zooplankton	1.3E-05
Benthic bacteria	1.0E-01	Meiobenthos	1.4E-01	J. sm. demersal fish	1.0E-05
Labile detritus	1.0E-01	Carn. macrobenthos	1.2E-01	Ad. sm. demersal fish	1.0E-05
Sm. phytoplankton	4.3E-03	Bivalves	1.0E-01	**J. lanternfish/deep**	
Lg. phytoplankton	3.5E-03	Scallops/penshells	1.0E-01	Labile detritus	1.0E-01
Carrion detritus	2.7E-03	Ad. lanternfish/deep	5.0E-02	Refractory detritus	1.0E-01
Sed. refractory detritus	2.7E-03	Sea cucumbers	5.0E-02	J. sm. reef fish	5.0E-02
Sed. carrion detritus	2.7E-03	Jellyfish	5.0E-02	Ad. sm. reef fish	5.0E-02
Sed. labile detritus	1.3E-03	Benthic bacteria	5.0E-02	Squid	3.8E-02
Microphytobenthos	1.0E-03	Sm. zooplankton	2.0E-02	Ad. sm. demersal fish	2.5E-02
Refractory detritus	1.0E-03	Macroalgae	2.0E-02	Sm. zooplankton	1.0E-02
Carn. macrobenthos	8.7E-05	Sessile invertebrates	1.0E-02	J. flatfish	6.7E-03
Lg. zooplankton	1.0E-05	Seagrass	1.0E-02	Ad. flatfish	6.1E-03
Meiobenthos	7.8E-06	Lg. zooplankton	1.0E-03	Lg. zooplankton	6.9E-05

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

J. sm. demersal fish	1.0E-05
J. lanternfish/deep	1.0E-05
Ad. lanternfish/deep	1.0E-05
Ad. lanternfish/deep	
Squid	1.1E-01
Labile detritus	1.0E-01
Refractory detritus	1.0E-01
J. sm. reef fish	5.0E-02
Ad. sm. reef fish	5.0E-02
Sm. zooplankton	5.0E-02
Ad. sm. demersal fish	1.1E-02
Scallops/penshells	1.0E-02
Crabs/lobsters	1.0E-02
Herb. echinoderms	1.0E-02
Jellyfish	1.0E-02
Meiobenthos	1.0E-02
Penaeid shrimp	1.0E-02
Sessile invertebrates	1.0E-03
Microphytobenthos	1.0E-03
Ad. flatfish	5.3E-04
J. flatfish	2.9E-04
Lg. zooplankton	1.0E-05
J. sm. demersal fish	1.0E-05
J. lanternfish/deep	1.0E-05
Ad. lanternfish/deep	1.0E-05
J. totoaba	
Carn. macrobenthos	9.0E-02
Meiobenthos	8.0E-02
J. sm. demersal fish	8.0E-02
Ad. sm. demersal fish	8.0E-02
Crabs/lobsters	8.0E-02
Penaeid shrimp	8.0E-02
Squid	7.0E-02
J. sm. reef fish	5.0E-02
Ad. sm. reef fish	5.0E-02
J. mackerel	4.0E-02
J. hake	4.0E-02
J. sm. pelagics	4.0E-02
Ad. mackerel	2.0E-02
Ad. hake	2.0E-02
Ad. sm. pelagics	2.0E-02
Ad. blue shrimp	1.0E-02
Sm. zooplankton	1.0E-02
Jellyfish	3.3E-03
Lg. zooplankton	1.0E-05
Ad. totoaba	
J. sm. demersal fish	1.0E-01
Ad. sm. demersal fish	1.0E-01
Squid	5.0E-02
J. sm. reef fish	5.0E-02
J. mackerel	5.0E-02
J. hake	5.0E-02
J. sm. pelagics	5.0E-02
J. blue shrimp	5.0E-02
Ad. sm. reef fish	5.0E-02
Ad. mackerel	5.0E-02
Ad. hake	5.0E-02
Ad. sm. pelagics	5.0E-02
Penaeid shrimp	4.0E-02
Crabs/lobsters	4.0E-02
Meiobenthos	4.0E-02
Carn. macrobenthos	2.0E-02
Ad. blue shrimp	1.0E-02
Ad. amarillo snapper	1.0E-03
Lg. zooplankton	1.0E-05
J. lg. pelagics	
Sm. zooplankton	4.0E-01
Sm. phytoplankton	2.0E-01
Squid	1.1E-01
J. skates, rays	1.0E-01
J. sm. pelagics	1.0E-01
Ad. Gulf grouper	1.0E-01
Ad. sm. pelagics	1.0E-01
Lg. phytoplankton	1.0E-01
Refractory detritus	1.0E-01
Meiobenthos	1.0E-01
Ad. barred pargo	8.5E-02
J. hake	7.0E-02
Ad. hake	7.0E-02
Ad. skates, rays	6.8E-02
J. scorpionfish	6.0E-02
Ad. scorpionfish	6.0E-02
J. mojarra	5.0E-02
J. lg. reef fish	5.0E-02
J. Gulf grouper	5.0E-02
Ad. mojarra	5.0E-02
Ad. guitarfish	2.5E-02
Ad. lg. reef fish	2.5E-02
Penaeid shrimp	2.0E-02
Ad. drums/croakers	1.9E-02
J. Gulf coney	1.0E-02
J. herbivorous fish	1.0E-02
J. leopard grouper	1.0E-02
J. lanternfish/deep	1.0E-02
Ad. Gulf coney	1.0E-02
Ad. herbivorous fish	1.0E-02
Ad. grunts	1.0E-02
Ad. extranjero	1.0E-02
Ad. leopard grouper	1.0E-02
Ad. lanternfish/deep	1.0E-02
Jellyfish	1.0E-02
Ad. groupers/snapper	7.6E-03
J. extranjero	5.0E-03
Ad. flatfish	2.5E-03
J. sm. demersal fish	1.0E-03
J. Pacific angel shark	1.0E-03
J. flatfish	1.0E-03
J. amarillo snapper	1.0E-03
J. groupers/snappers	1.0E-03
J. drums/croakers	1.0E-03
J. barred pargo	1.0E-03
Ad. sm. demersal fish	1.0E-03
Ad. Pacific angel shark	1.0E-03
Ad. amarillo snapper	1.0E-03
Ad. sm. reef fish	3.9E-04
J. grunts	1.0E-04
J. mackerel	1.0E-04
Ad. mackerel	1.0E-04
Microphytobenthos	1.0E-04
Lg. zooplankton	1.0E-05
J. lg. pelagics	1.0E-06
Ad. lg. pelagics	1.0E-06
Crabs/lobsters	5.8E-07
Labile detritus	3.3E-07
Sessile invertebrates	1.5E-07
Carrion detritus	1.3E-07
Carn. macrobenthos	1.1E-07
Herb. echinoderms	6.1E-08
Macroalgae	1.9E-08
Ad. blue shrimp	1.8E-08
Bivalves	1.4E-08
Seagrass	1.1E-09
J. sm. mig. sharks	1.0E-10
Ad. sm. mig. sharks	1.0E-10
Ad. lg. pelagics	
Sm. zooplankton	3.0E-01
J. mojarra	1.0E-01
Ad. scorpionfish	1.0E-01
Ad. mojarra	1.0E-01
Ad. sm. pelagics	1.0E-01
Squid	7.0E-02
Ad. barred pargo	6.1E-02
J. scorpionfish	6.0E-02
J. hake	5.0E-02
J. sm. pelagics	5.0E-02
J. blue shrimp	5.0E-02
Ad. Gulf grouper	5.0E-02

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

Ad. hake	5.0E-02	Herb. echinoderms	6.2E-08	Ad. mackerel	1.0E-04
Refractory detritus	5.0E-02	Macroalgae	1.9E-08	Lg. zooplankton	1.0E-05
Ad. skates, rays	4.9E-02	Bivalves	1.4E-08	Carrion detritus	1.8E-06
Ad. grunts	2.6E-02	Seagrass	1.1E-09	Ad. blue shrimp	1.7E-06
Penaeid shrimp	2.0E-02	J. sm. mig. sharks	1.0E-10	J. lg. pelagics	1.0E-06
Jellyfish	2.0E-02	Ad. sm. mig. sharks	1.0E-10	Ad. lg. pelagics	1.0E-06
J. skates, rays	2.0E-02	**J. mackerel**		Crabs/lobsters	8.0E-07
Ad. guitarfish	1.8E-02	Sm. zooplankton	2.0E-01	Carn. macrobenthos	2.9E-07
Ad. drums/croakers	1.3E-02	Lg. phytoplankton	1.0E-01	Bivalves	1.9E-07
J. Gulf grouper	1.0E-02	Sm. phytoplankton	1.0E-01	J. sm. mig. sharks	1.0E-07
J. herbivorous fish	1.0E-02	Squid	3.5E-02	Ad. sm. mig. sharks	1.0E-07
J. leopard grouper	1.0E-02	Crabs/lobsters	1.0E-02	Seagrass	1.5E-08
Ad. Gulf coney	1.0E-02	Meiobenthos	1.0E-02	**J. hake**	
Ad. herbivorous fish	1.0E-02	Jellyfish	1.0E-02	Sm. zooplankton	1.0E-01
Ad. leopard grouper	1.0E-02	Labile detritus	1.0E-02	Ad. sm. demersal fish	1.0E-02
Ad. lanternfish/deep	1.0E-02	Refractory detritus	1.0E-02	Crabs/lobsters	5.0E-03
Ad. groupers/snapper	5.4E-03	Seagrass	5.0E-03	Penaeid shrimp	1.0E-03
Ad. extranjero	5.0E-03	Ad. blue shrimp	1.0E-03	Meiobenthos	8.3E-04
J. extranjero	4.4E-03	J. mackerel	1.0E-03	Ad. blue shrimp	1.7E-04
J. Gulf coney	4.3E-03	Ad. mackerel	1.0E-03	Lg. zooplankton	1.0E-05
J. lg. reef fish	3.0E-03	Penaeid shrimp	1.0E-03	**Ad. hake**	
J. guitarfish	2.0E-03	J. hake	3.0E-04	Sm. zooplankton	8.0E-02
Ad. flatfish	1.8E-03	J. sm. pelagics	3.0E-04	J. blue shrimp	5.0E-02
J. amarillo snapper	1.0E-03	Ad. hake	3.0E-04	Crabs/lobsters	2.3E-03
Ad. amarillo snapper	1.0E-03	Ad. sm. pelagics	3.0E-04	Ad. blue shrimp	1.2E-03
J. flatfish	9.8E-04	J. sm. mig. sharks	1.0E-05	Refractory detritus	1.0E-03
J. groupers/snappers	4.9E-04	Ad. sm. mig. sharks	1.0E-05	Meiobenthos	3.7E-04
J. barred pargo	4.2E-04	Carrion detritus	1.0E-05	Penaeid shrimp	2.5E-05
J. lanternfish/deep	4.0E-04	Lg. zooplankton	1.0E-05	Lg. zooplankton	1.0E-05
J. grunts	1.0E-04	J. lg. pelagics	1.0E-06	**J. oceanic turtles**	
J. drums/croakers	1.0E-04	Ad. lg. pelagics	1.0E-06	Jellyfish	1.0E-01
J. mackerel	1.0E-04	Carn. macrobenthos	2.8E-07	Carn. macrobenthos	1.0E-02
Ad. lg. reef fish	1.0E-04	Bivalves	1.9E-07	J. sm. demersal fish	1.0E-03
Ad. mackerel	1.0E-04	**Ad. mackerel**		J. flatfish	1.0E-03
Lg. zooplankton	1.0E-05	Sm. zooplankton	1.5E-01	J. sm. reef fish	1.0E-03
J. Pacific angel shark	1.0E-05	Lg. phytoplankton	7.0E-02	Ad. sm. demersal fish	1.0E-03
Ad. Pacific angel shark	1.0E-05	J. blue shrimp	5.0E-02	Ad. sm. reef fish	1.0E-03
J. lg. pelagics	1.0E-06	Sm. phytoplankton	5.0E-02	Bivalves	1.0E-03
Ad. lg. pelagics	1.0E-06	Squid	2.1E-02	Crabs/lobsters	1.0E-04
Crabs/lobsters	5.9E-07	Penaeid shrimp	1.0E-02	Meiobenthos	1.0E-04
Lg. phytoplankton	4.3E-07	Jellyfish	1.0E-02	Snails	1.0E-04
Sm. phytoplankton	4.3E-07	Labile detritus	5.0E-04	Refractory detritus	1.0E-04
Labile detritus	3.3E-07	Refractory detritus	5.0E-04	**Ad. oceanic turtles**	
Sessile invertebrates	1.5E-07	J. hake	3.0E-04	Jellyfish	6.0E-01
Carrion detritus	1.3E-07	J. sm. pelagics	3.0E-04	Carn. macrobenthos	2.0E-01
Ad. blue shrimp	1.3E-07	Ad. hake	3.0E-04	Sea cucumbers	1.5E-01
Carn. macrobenthos	1.1E-07	Ad. sm. pelagics	3.0E-04	Meiobenthos	1.5E-01
Meiobenthos	9.7E-08	Meiobenthos	1.0E-04	Bivalves	1.0E-01
Microphytobenthos	9.5E-08	J. mackerel	1.0E-04	Penaeid shrimp	1.0E-01

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

Scallops/penshells	1.0E-01
Refractory detritus	1.0E-01
Squid	7.0E-02
J. sm. demersal fish	1.0E-02
J. flatfish	1.0E-02
J. sm. reef fish	1.0E-02
J. groupers/snappers	1.0E-02
J. lg. pelagics	1.0E-02
J. mackerel	1.0E-02
J. hake	1.0E-02
J. sm. pelagics	1.0E-02
Ad. sm. demersal fish	1.0E-02
Ad. sm. reef fish	1.0E-02
Ad. lg. pelagics	1.0E-02
Ad. mackerel	1.0E-02
Ad. hake	1.0E-02
Ad. sm. pelagics	1.0E-02
Lg. zooplankton	1.0E-04
J. sm. pelagics	
Sm. phytoplankton	5.0E-01
Sm. zooplankton	4.0E-01
Lg. phytoplankton	2.0E-01
Labile detritus	1.0E-01
Squid	7.0E-02
Microphytobenthos	1.0E-02
Jellyfish	3.3E-03
Refractory detritus	1.0E-03
Ad. blue shrimp	8.2E-04
J. hake	1.0E-04
J. sm. pelagics	1.0E-04
Ad. sm. pelagics	1.0E-04
Penaeid shrimp	5.7E-05
Crabs/lobsters	2.4E-05
Ad. hake	1.0E-05
Lg. zooplankton	1.0E-05
Carn. macrobenthos	8.9E-06
Meiobenthos	4.0E-06
Ad. sm. pelagics	
Sm. phytoplankton	4.0E-01
Sm. zooplankton	4.0E-01
Lg. phytoplankton	2.0E-01
Labile detritus	1.0E-01
Squid	7.0E-02
Ad. blue shrimp	5.8E-03
Jellyfish	3.3E-03
Refractory detritus	1.0E-03
J. hake	1.0E-04
J. sm. pelagics	1.0E-04
Ad. sm. pelagics	1.0E-04
Penaeid shrimp	5.9E-05
Crabs/lobsters	2.5E-05
Lg. zooplankton	1.0E-05
Ad. hake	1.0E-05
Carn. macrobenthos	9.2E-06
Meiobenthos	4.2E-06
J. vaquita	
Ad. lanternfish/deep	3.6E-01
J. grunts	2.0E-01
Ad. grunts	2.0E-01
Ad. drums/croakers	2.0E-01
J. sm. pelagics	1.0E-01
Ad. sm. pelagics	1.0E-01
Ad. mojarra	9.9E-02
Ad. groupers/snappers	8.0E-02
Crabs/lobsters	7.0E-02
Carn. macrobenthos	7.0E-02
J. mojarra	5.0E-02
J. drums/croakers	5.0E-02
J. totoaba	5.0E-02
Ad. totoaba	5.0E-02
Ad. sm. demersal fish	2.1E-02
J. herbivorous fish	2.0E-02
J. lanternfish/deep	1.9E-02
J. sm. demersal fish	1.2E-02
J. scorpionfish	1.0E-02
Ad. hake	2.6E-03
J. hake	1.3E-03
J. flatfish	1.0E-03
Squid	7.0E-04
J. groupers/snappers	1.0E-04
Ad. vaquita	
J. grunts	2.0E-01
J. sm. pelagics	2.0E-01
Ad. sm. pelagics	2.0E-01
Ad. grunts	1.5E-01
Ad. drums/croakers	1.3E-01
Ad. lanternfish/deep	1.1E-01
J. scorpionfish	1.0E-01
J. mojarra	1.0E-01
Ad. scorpionfish	1.0E-01
Ad. flatfish	1.0E-01
Ad. mojarra	1.0E-01
J. drums/croakers	5.0E-02
Ad. totoaba	5.0E-02
J. totoaba	4.0E-02
Ad. groupers/snappers	2.5E-02
J. herbivorous fish	2.0E-02
Ad. herbivorous fish	2.0E-02
Ad. sm. demersal fish	6.5E-03
J. lanternfish/deep	5.9E-03
J. sm. demersal fish	3.7E-03
J. groupers/snappers	2.0E-03
J. flatfish	1.0E-03
Ad. hake	7.8E-04
Squid	7.0E-04
J. hake	4.1E-04
Carn. macrobenthos	3.6E-06
Crabs/lobsters	1.7E-06
J. Mysticeti	
Sm. zooplankton	1.0E-01
Ad. blue shrimp	5.0E-02
Lg. phytoplankton	5.0E-02
Sm. phytoplankton	5.0E-02
Pelagic bacteria	5.0E-02
Squid	3.0E-02
Jellyfish	2.0E-02
J. sm. pelagics	1.0E-03
Ad. sm. pelagics	1.0E-03
Lg. zooplankton	1.0E-03
J. lg. pelagics	1.0E-04
Ad. lg. pelagics	1.0E-04
Ad. Mysticeti	
Pelagic bacteria	8.0E-02
Ad. blue shrimp	5.0E-02
Jellyfish	4.0E-02
Squid	4.0E-02
Sm. zooplankton	5.0E-03
J. sm. pelagics	1.0E-03
Ad. sm. pelagics	1.0E-03
Lg. phytoplankton	1.0E-03
Sm. phytoplankton	1.0E-03
Lg. zooplankton	1.0E-05
J. Orca	
Ad. pinnipeds	3.0E-01
J. pinnipeds	1.0E-01
J. reef turtles	1.0E-01
Ad. lg. pelagics	1.0E-01
Ad. reef turtles	1.0E-01
Squid	7.0E-02
Ad. mackerel	5.0E-02
Ad. hake	5.0E-02
Ad. sm. pelagics	5.0E-02
J. Odontocetae	4.4E-02
Ad. Mysticeti	1.3E-02
Ad. Odontocetae	1.3E-02
J. oceanic turtles	1.0E-02
Ad. oceanic turtles	1.0E-02

Table A-9 continued. Availability matrix. Predator is in boldface, followed by prey species.

J. Mysticeti	8.6E-03
J. sm. demersal fish	1.0E-03
J. lg. pelagics	1.0E-03
J. mackerel	1.0E-03
J. hake	1.0E-03
J. sm. pelagics	1.0E-03
Ad. sm. demersal fish	1.0E-03
Jellyfish	1.0E-03
J. lg. pelagic sharks	1.0E-05
Ad. lg. pelagic sharks	1.0E-05
Ad. Gulf grouper	1.0E-05
Ad. amarillo snapper	1.0E-05
Ad. orca	
J. pinnipeds	3.0E-01
Ad. pinnipeds	3.0E-01
J. lg. pelagics	1.0E-01
J. mackerel	1.0E-01
J. sm. pelagics	1.0E-01
J. oceanic turtles	1.0E-01
J. Mysticeti	1.0E-01
J. Odontocetae	1.0E-01
Ad. lg. pelagics	1.0E-01
J. hake	9.0E-02
J. reef turtles	5.8E-02
Ad. reef turtles	3.7E-02
J. sm. demersal fish	1.0E-02
J. orca	1.0E-02
Ad. sm. demersal fish	1.0E-02
Ad. hake	1.0E-02
Ad. sm. pelagics	1.0E-02
Ad. oceanic turtles	1.0E-02
Ad. Mysticeti	1.0E-02
Ad. Odontocetae	1.0E-02
J. lg. pelagic sharks	1.0E-03
Ad. lg. pelagic sharks	1.0E-03
Ad. Gulf grouper	1.0E-03
Ad. drums/croakers	1.0E-03
Ad. mackerel	1.0E-03
Ad. orca	1.0E-03
Ad. amarillo snapper	1.0E-04
J. Odontocetae	
J. sm. pelagics	1.0E-01
Ad. sm. pelagics	1.0E-01
Ad. lg. pelagics	2.0E-02
J. grunts	1.0E-02
J. lanternfish/deep	1.0E-02
J. lg. pelagics	1.0E-02
J. mackerel	1.0E-02
J. hake	1.0E-02
Ad. grunts	1.0E-02
Ad. lanternfish/deep	1.0E-02
Ad. mackerel	1.0E-02
Ad. hake	1.0E-02
Squid	7.0E-03
J. sm. demersal fish	1.0E-03
J. mojarra	1.0E-03
J. groupers/snappers	1.0E-03
Ad. sm. demersal fish	1.0E-03
Ad. mojarra	1.0E-03
Ad. groupers/snapper	1.0E-03
Ad. lg. reef fish	6.3E-04
Jellyfish	3.3E-04
J. lg. reef fish	2.5E-04
Ad. sm. reef fish	3.4E-05
J. sm. reef fish	5.8E-06
Ad. Odontocetae	
Ad. hake	6.0E-02
J. mackerel	5.0E-02
Ad. mackerel	5.0E-02
Ad. sm. pelagics	5.0E-02
J. groupers/snappers	2.0E-02
Ad. groupers/snapper	2.0E-02
J. grunts	1.0E-02
J. hake	1.0E-02
Ad. grunts	1.0E-02
Jellyfish	1.0E-02
Squid	1.0E-02
J. lg. pelagics	8.0E-03
Ad. lg. pelagics	8.0E-03
J. lanternfish/deep	5.0E-03
J. sm. pelagics	5.0E-03
Ad. lanternfish/deep	5.0E-03
Ad. lg. reef fish	2.0E-03
Ad. sm. reef fish	2.0E-03
J. sm. demersal fish	1.0E-03
J. mojarra	1.0E-03
J. lg. reef fish	1.0E-03
J. sm. reef fish	1.0E-03
Ad. sm. demersal fish	1.0E-03
Ad. mojarra	1.0E-03
Jellyfish	
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Labile detritus	1.0E-01
Sm. zooplankton	5.0E-03
Lg. zooplankton	1.2E-03
Refractory detritus	1.0E-03
Jellyfish	2.0E-04
Macroalgae	1.8E-06
Lg. zooplankton	
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Sm. zooplankton	2.0E-01
Sm. phytoplankton	1.0E-01
Refractory detritus	5.0E-02
Labile detritus	1.0E-02
Lg. phytoplankton	1.7E-03
Jellyfish	1.0E-04
Microphytobenthos	2.2E-07
Squid	
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Pelagic bacteria	3.0E-01
Benthic bacteria	2.0E-01
Lg. zooplankton	5.0E-02
Penaeid shrimp	5.0E-02
Refractory detritus	5.0E-02
Sm. phytoplankton	5.0E-02
Labile detritus	1.0E-02
Ad. sm. pelagics	1.0E-03
Lg. phytoplankton	1.0E-03
Refractory detritus	1.0E-03
Carn. macrobenthos	4.2E-04
Ad. lanternfish/deep	3.3E-04
Squid	1.1E-04
Crabs/lobsters	1.0E-04
Jellyfish	1.0E-04
Meiobenthos	8.8E-06
Macroalgae	3.7E-08
Microphytobenthos	6.8E-09
Sm. zooplankton	
Pelagic bacteria	5.0E-01
Benthic bacteria	5.0E-01
Sm. phytoplankton	5.0E-02
Refractory detritus	1.0E-03
Microphytobenthos	6.8E-09

Appendix B: Basic Parameterization

This appendix contains the following figures and tables.

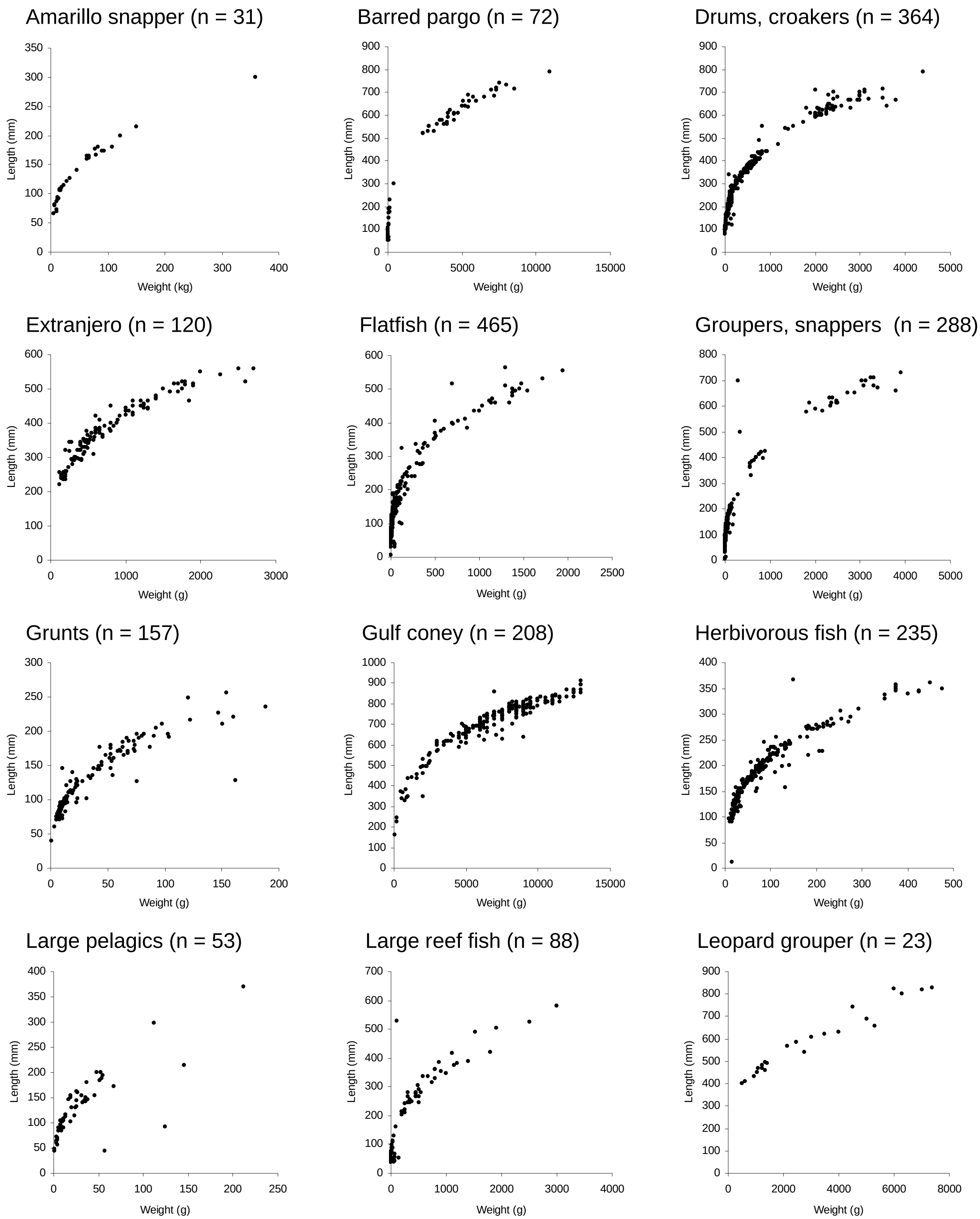


Figure B-1. Length (y-axis)-weight (x-axis) relationships determined from sampling for 12 functional groups. Related statistics are in Table B-1. Sources: this volume (n = 404), PANGAS field sampling database (n = 441), Alfredo Arreola unpubl. data (n = 3,697).

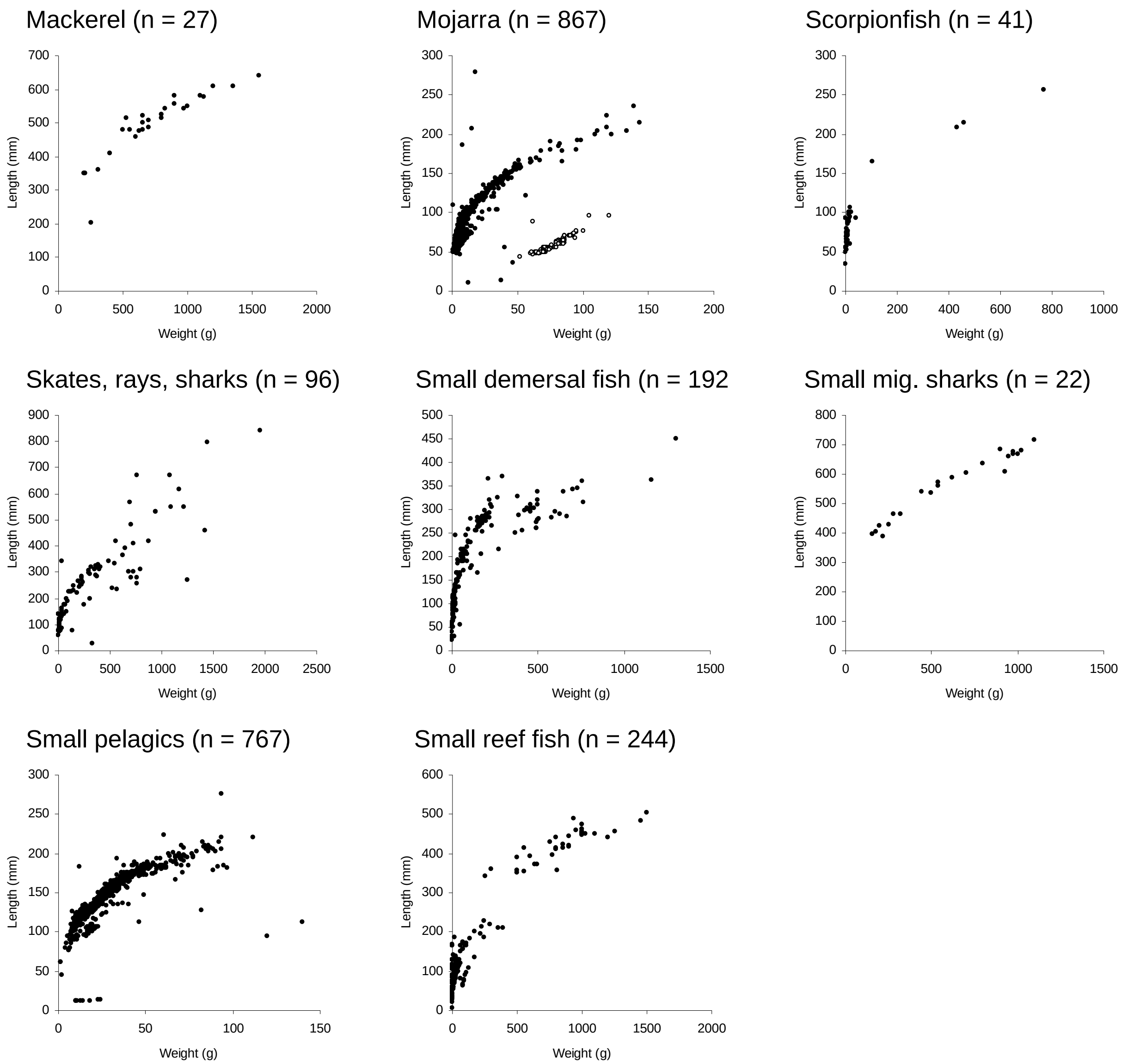


Figure B-2. Length (y-axis)-weight (x-axis) relationships determined from sampling for eight functional groups. Related statistics are in Table B-1. Sources: this volume (n = 404), PANGAS field sampling database (n = 441), Alfredo Arreola unpubl. data (n = 3,697). (Open circles in mojarra chart were not used in length-weight parameter calculations.)

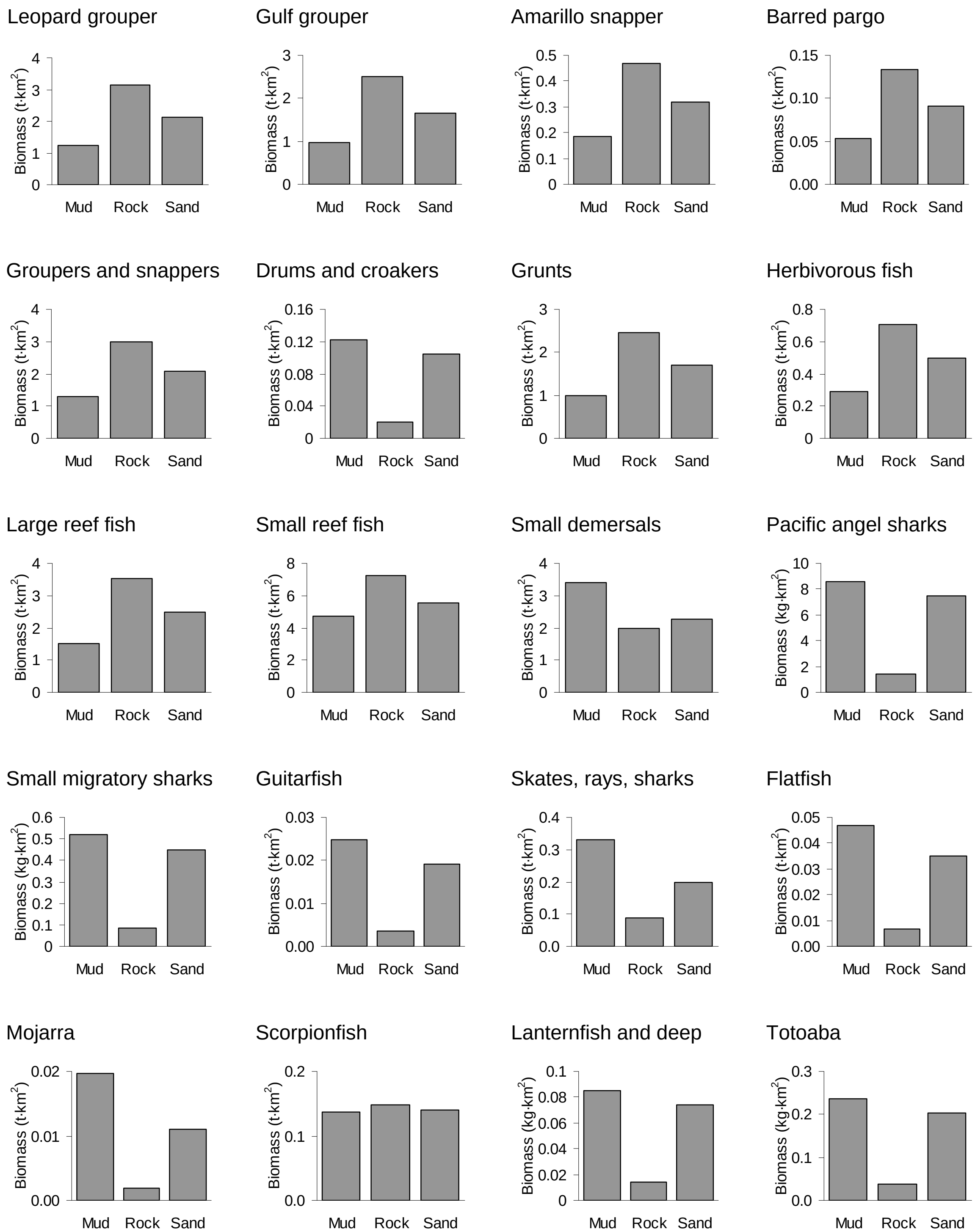


Figure B-3. Biomass by sediment type predicted by biomass allocation algorithm for 20 functional groups.

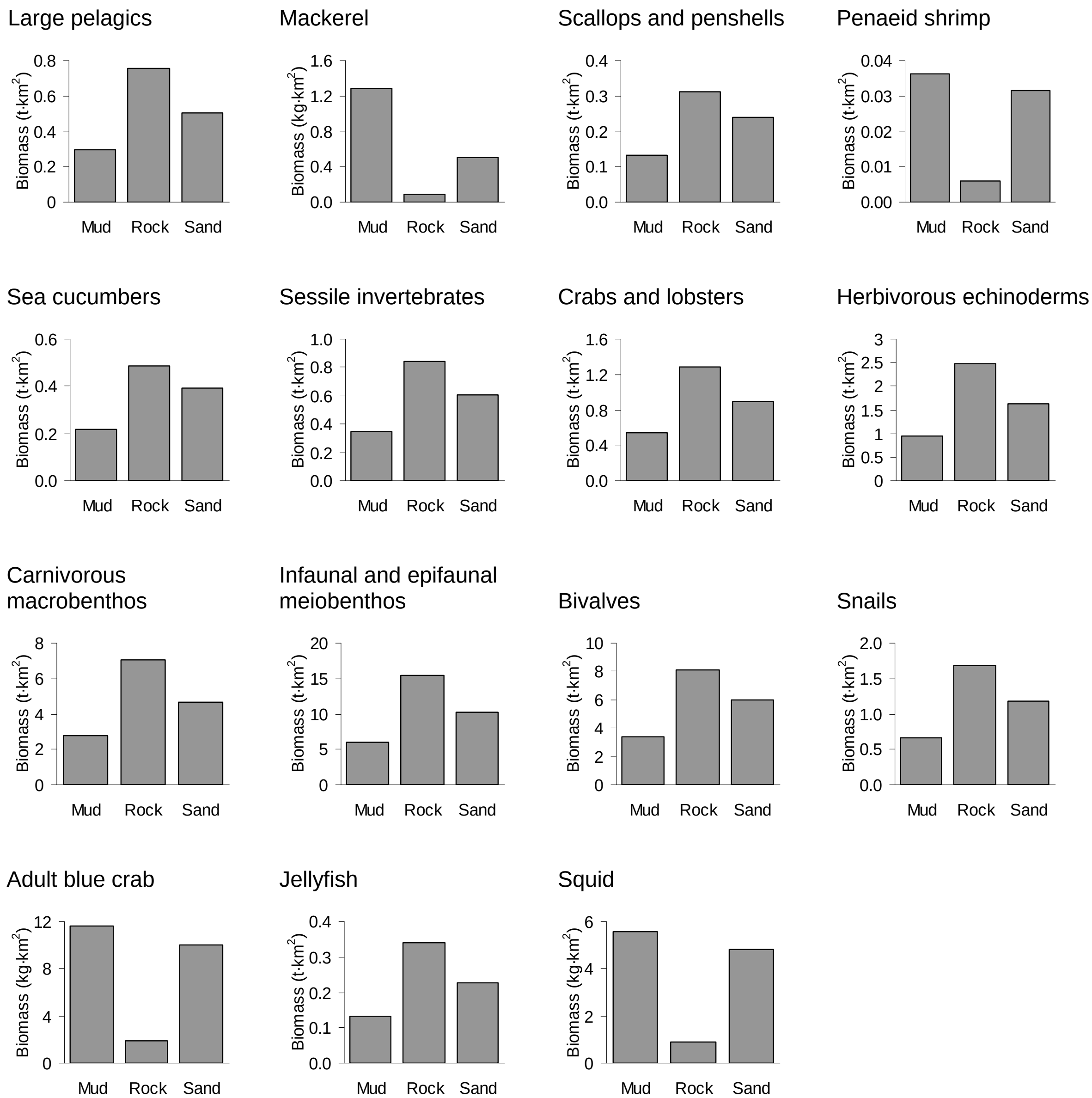


Figure B-4. Biomass by sediment type predicted by biomass allocation algorithm for 15 functional groups.

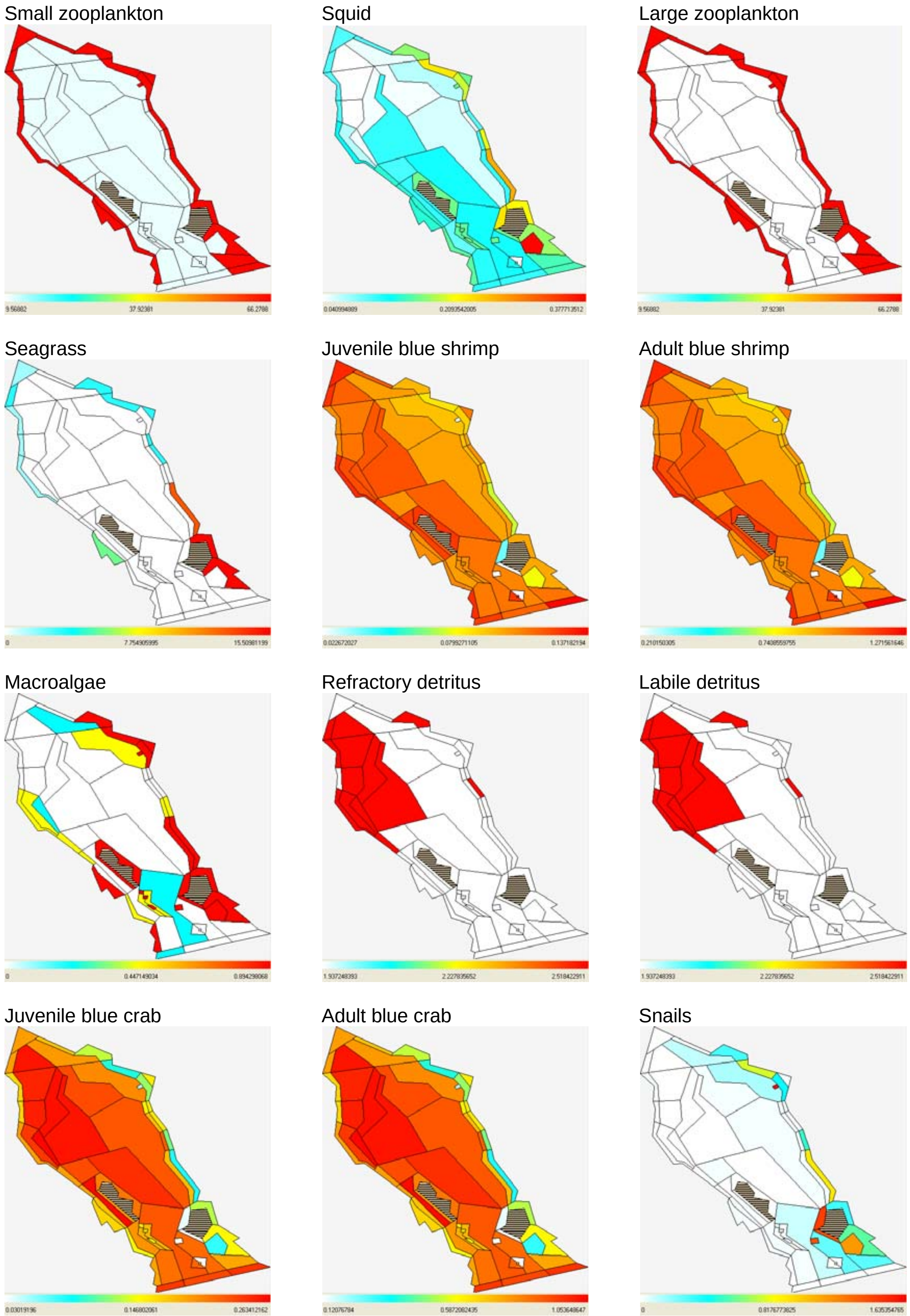


Figure B-5. Spatial biomass distributions of 12 functional groups by polygon for 2008 model.

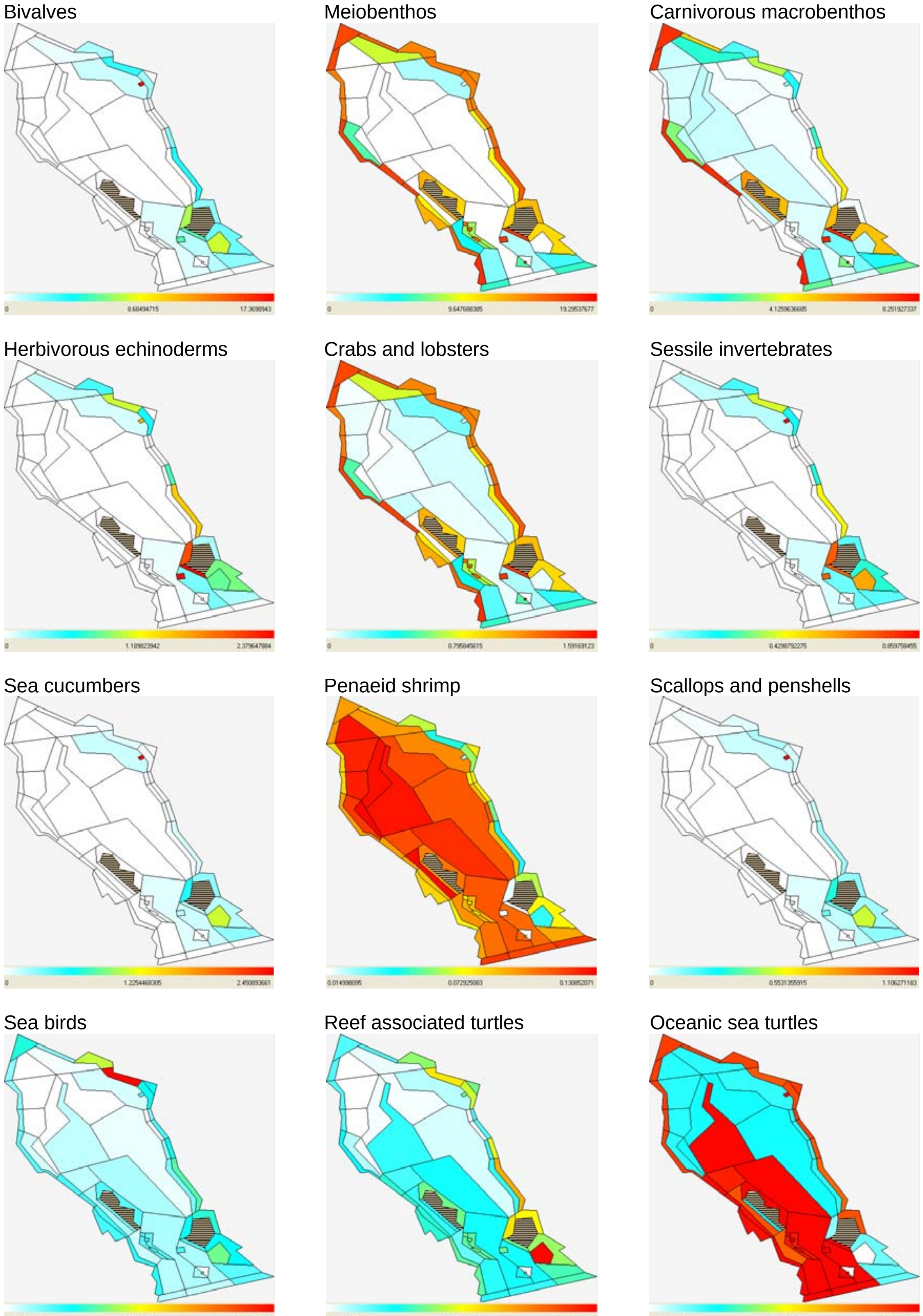


Figure B-6. Spatial biomass distributions of 12 functional groups by polygon for 2008 model.

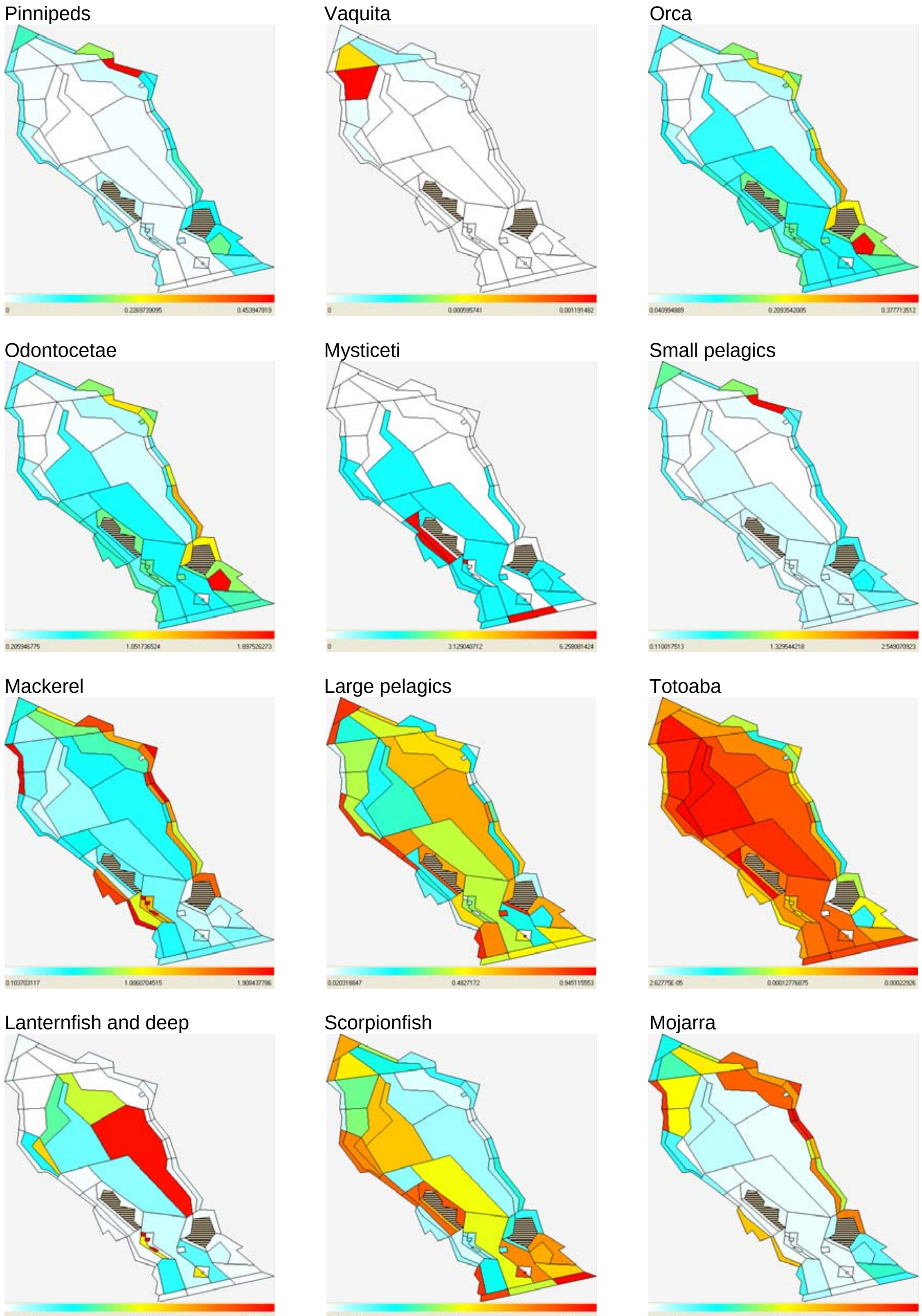


Figure B-7. Spatial biomass distributions of 12 functional groups by polygon for 2008 model.

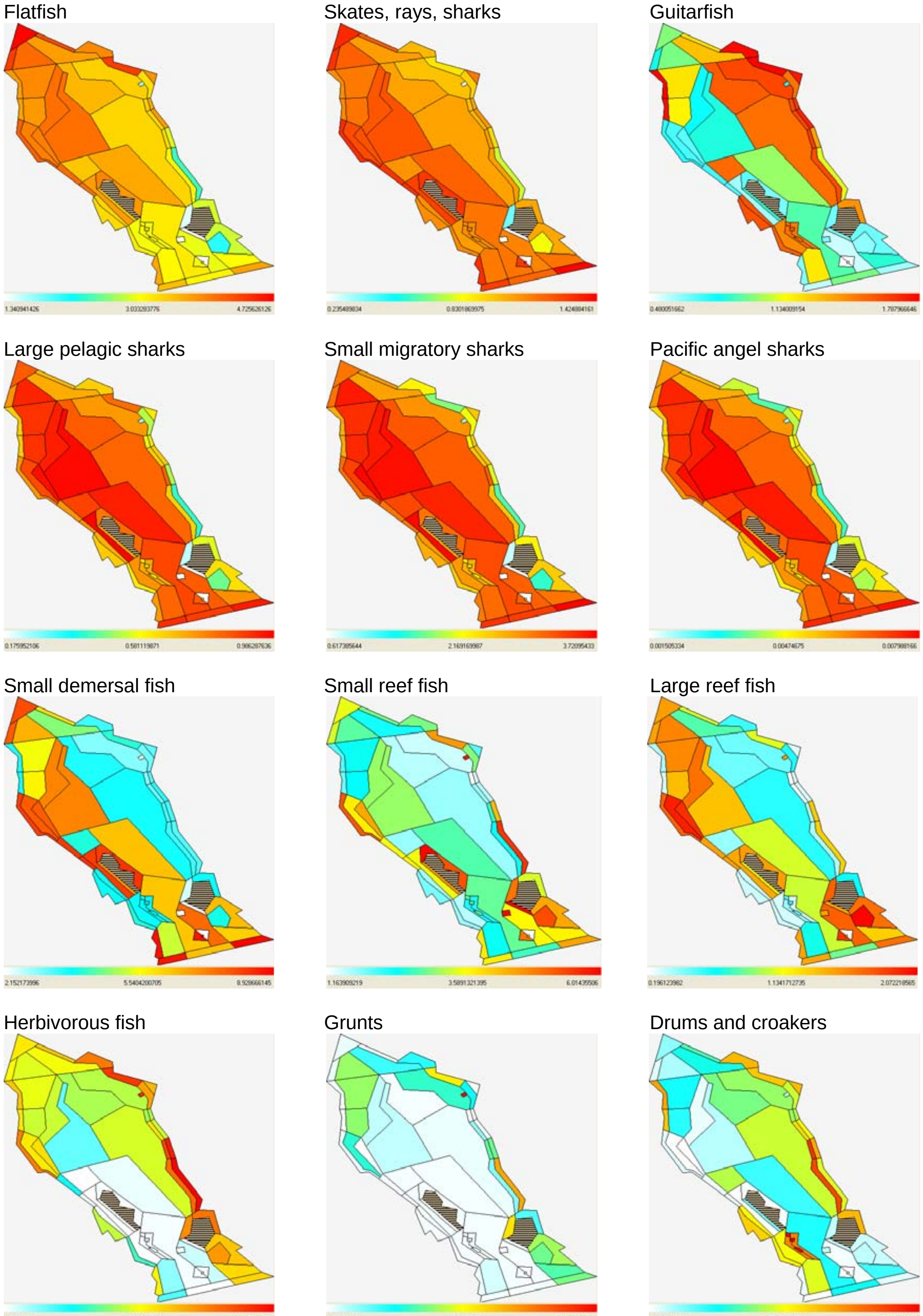


Figure B-8. Spatial biomass distributions of 12 functional groups by polygon for 2008 model.

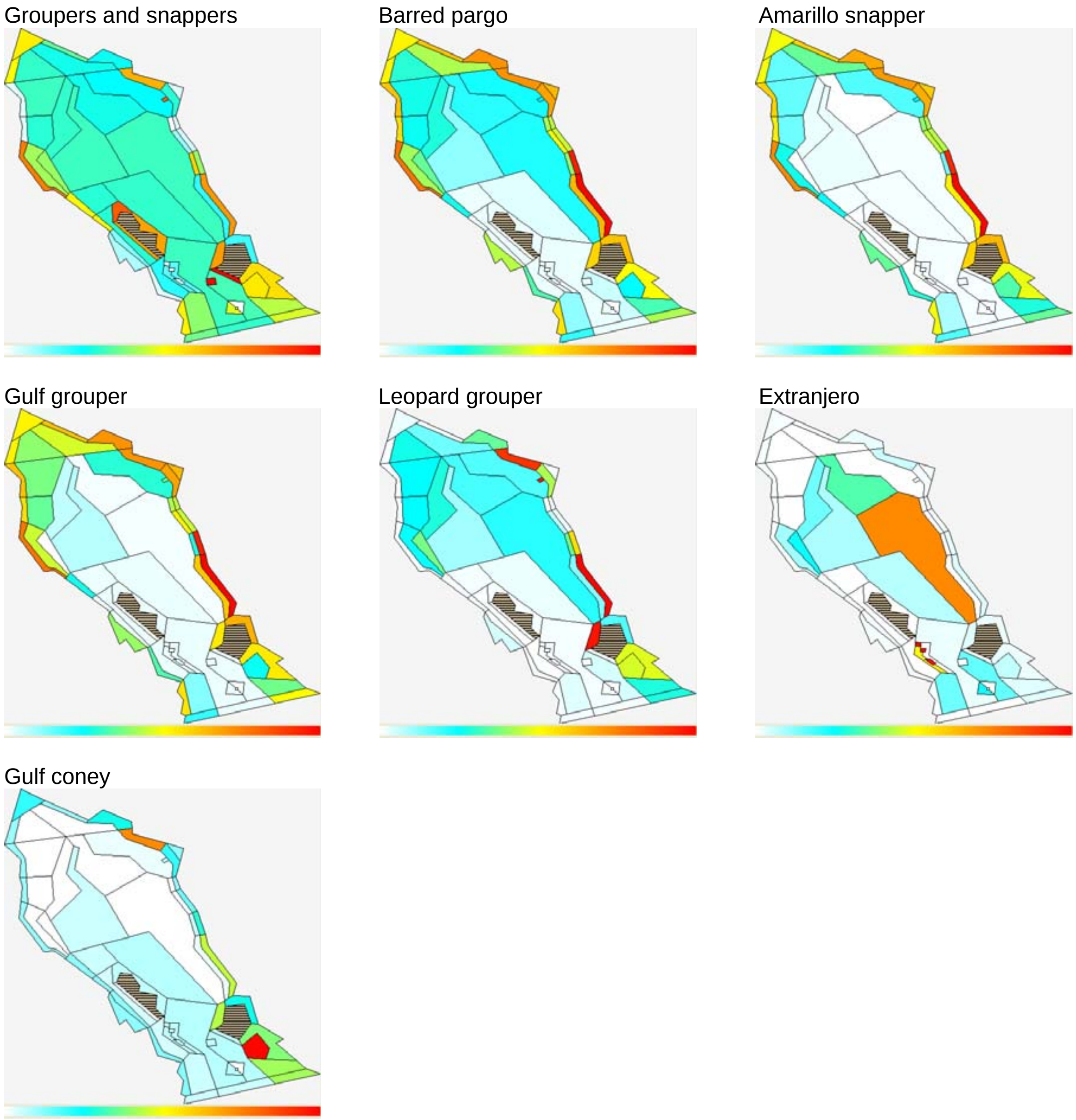


Figure B-9. Spatial biomass distributions of seven functional groups by polygon for 2008 model.

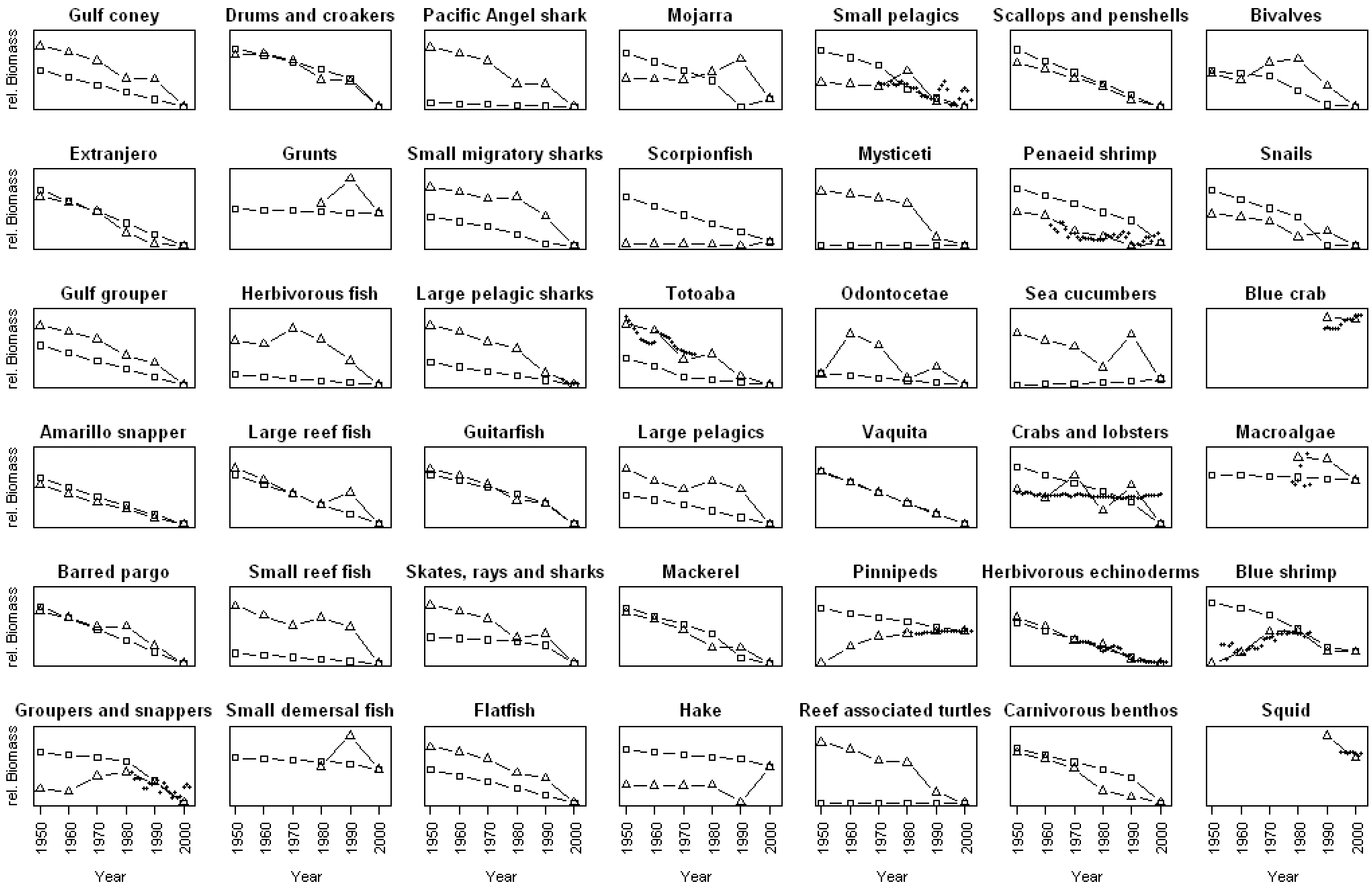


Figure B-10. Relative biomass time series. Reproduced from Ainsworth (in press). Triangles represent trend determined from abundance indicators, squares represent trend from exploitation indicators, and points represent empirical data from literature. Y scale is relative.

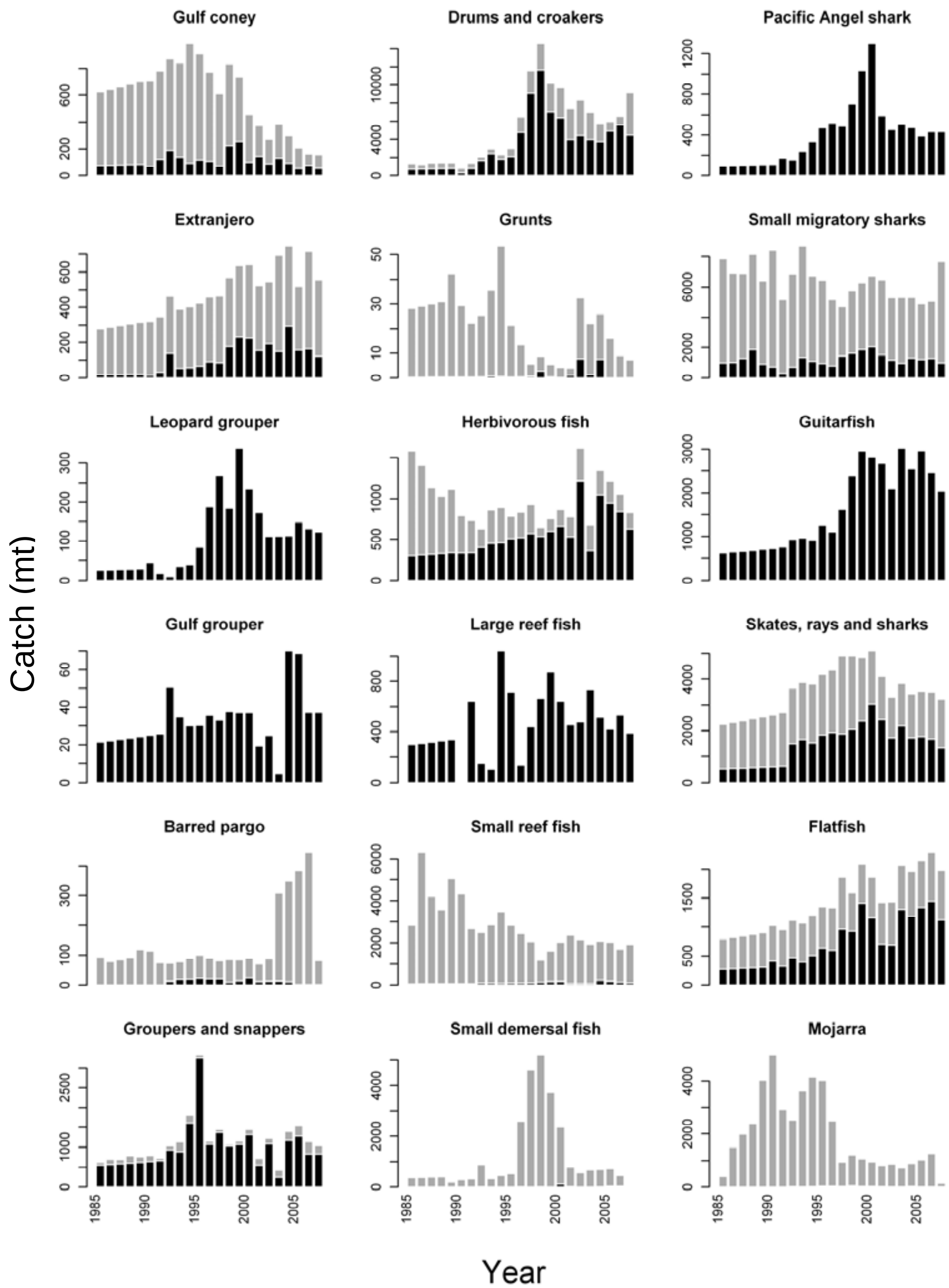


Figure B-11. Catch reconstruction for 18 northern Gulf of California functional groups. Gray bars show catch from official government statistics: Carte Nationale (Diario Oficial de la Federación 2004b, 2006b), Anuario Estadistico (Conapesca 2009). Black bars show data collected by PANGAS project (Valdéz-Ornelas and Torreblanca unpubl. data), port-level surveys (Perez-Valencia unpubl. data), and other literature sources (Table 9). Catch values used to drive historical simulation (1985–2008) were further multiplied by factors in Table 5 to account for discards and unreported catch.

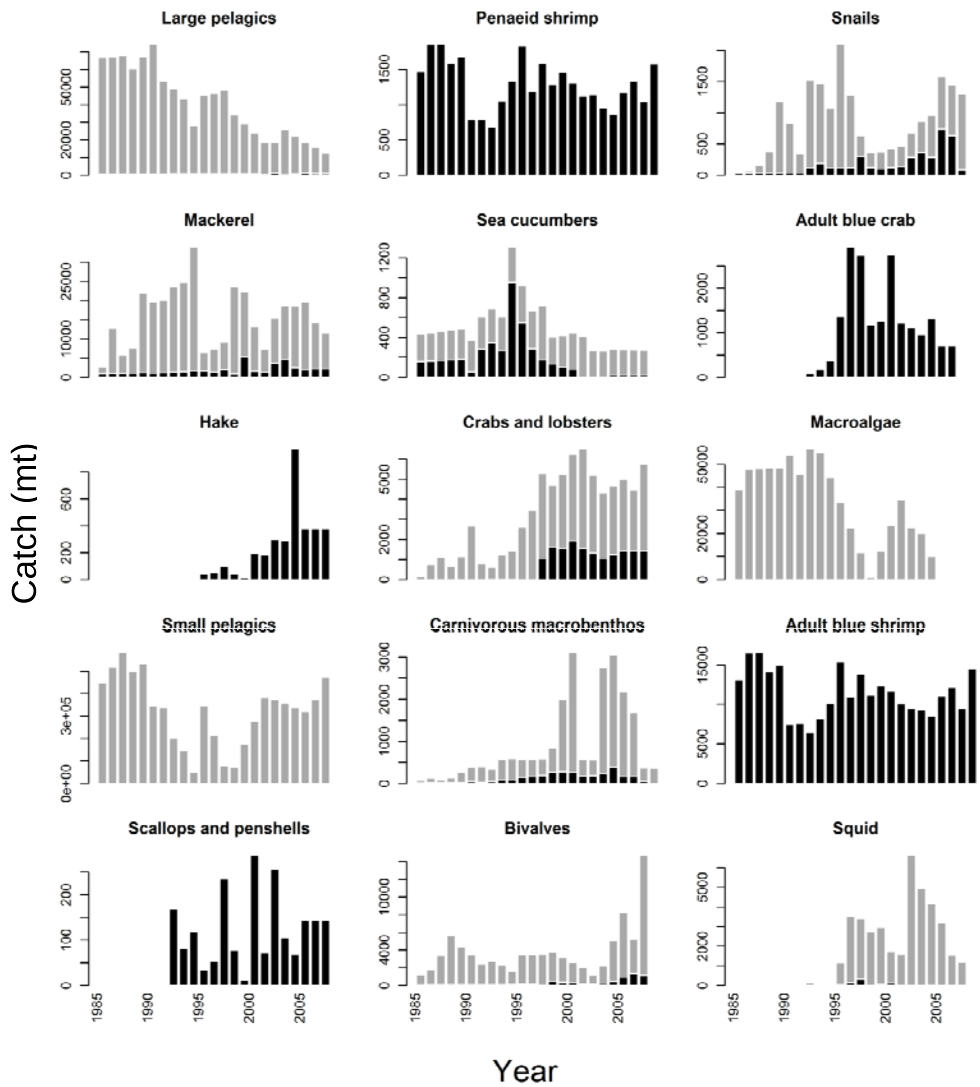


Figure B-12. Catch reconstruction for 15 northern Gulf of California functional groups. Gray bars show catch from official government statistics: Carte Nationale (Diario Oficial de la Federación 2004b, 2006b), Anuario Estadistico (Conapesca 2009). Black bars show data collected by PANGAS project (Valdéz-Ornelas and Torreblanca unpubl. data), port-level surveys (Perez-Valencia unpubl. data), and other literature sources (Table 9). Catch values used to drive historical simulation (1985–2008) were further multiplied by factors in Table 5 to account for discards and unreported catch.

Table B-1. Length-weight statistics (a and b) for Atlantis groups based on sampling (n = number of samples, r^2 = squared residuals).

Group	a	b	n	r^2
Amarillo snapper	3.91E-05	2.818	31	0.976
Barred pargo	1.29E-04	2.696	72	0.968
Drums and croakers	1.50E-05	2.920	364	0.971
Extranjero	4.40E-06	3.173	120	0.944
Flatfish	1.59E-04	2.479	465	0.837
Groupers and snappers	2.18E-04	2.450	288	0.853
Grunts	4.98E-05	2.728	157	0.920
Gulf coney	9.80E-06	3.093	208	0.955
Gulf grouper	3.21E-01	1.517	16	0.825
Herbivorous fish	1.05E-03	2.120	235	0.793
Large pelagics	9.67E-04	2.060	53	0.669
Large reef fish	3.40E-04	2.491	88	0.853
Leopard grouper	1.40E-06	3.341	23	0.950
Mackerel	3.42E-03	1.968	27	0.762
Mojarra	1.09E-03	2.016	867	0.626
Scorpionfish	2.60E-06	3.438	41	0.778
Skates, rays, sharks	1.07E-03	2.183	96	0.689
Small demersal fish	2.60E-05	2.831	192	0.872
Small migratory sharks	1.10E-06	3.162	22	0.975
Small pelagics	4.52E-02	1.273	767	0.417
Small reef fish	9.10E-05	2.648	244	0.749

Table B-2. Biomass in 2008 and 1985 Atlantis models. Biomass (B) present in the Gulf of California as of January 1 (seasonal migrators: SB, WHB, and WHT). B_{1950} is from Lozano 2006.

Functional group	**Code**	**B_{2008}**	**B_{1950}**	**B_{2008}/B_{1950}**	**B_{1985}**	**B_{2008}/B_{1985}**	**B_{1985} parameterization method**
Gulf coney	FBP	5,012			15,275	33%	CPUE
Extranjero	FDB	6,243			1,637	381%	Unchanged from 2008[a]
Leopard grouper	FDC	3,600			13,014	28%	CPUE
Gulf grouper	FDD	2,966			3,317	89%	CPUE
Amarillo snapper	FDE	3,480			11,656	30%	(As FDM)
Barred pargo	FDF	1,795			1,853	97%	CPUE
Groupers and snappers	FDM	39,546	237,096	17%	152,870	26%	LEK
Drums and croakers	FDO	160,404	2,055,351	8%	935,218	17%	LEK
Grunts	FDP	2,795	347,898	1%	41,247	7%	LEK
Herbivorous fish	FDS	14,740			28,035	53%	CPUE
Large reef fish	FMM	57,051			122,935	46%	CPUE
Small reef fish	FMN	152,407			620,879	25%	CPUE
Small demersal fish	FPL	302,413	1,998,608	15%	1,257,666	24%	LEK
Pacific angel shark	FPS	3,693			5,241	70%	CPUE
Sm. migratory sharks	FPO	172,926			605,747	29%	CPUE
Large pelagic sharks	FVB	45,692	94,000	49%	61,222	75%	LEK
Guitarfish	FVD	63,805	192,127	33%	107,115	60%	LEK
Skates, rays, sharks	FVO	62,321	488,063	13%	242,860	26%	LEK
Flatfish	FVS	38,690	130,686	30%	34,639	112%	LEK
Mojarra	FVT	23,881	807,119	3%	49,588	48%	LEK
Scorpionfish	FVV	8,805	28,000	31%	13,815	64%	LEK
Lanternfish and deep	SHB	109,323	234,032	47%	142,004	77%	LEK
Totoaba	SHC	10	124,848	0.01%	11,560	0.09%	Stock assessement[b]
Large pelagics	SHD	25,761			64,177	40%	CPUE
Mackerel	SHP	30,375			4,164	729%	CPUE
Hake	SHR	28,322			1,263	2,242%	CPUE[c]
Small pelagics	SSK	180,450	207,329	87%	80,966	223%	LEK
Mysticeti	WHB	45,553	25,490	179%	37,147	123%	LEK
Odontocetae	WHT	28,050	16,126	174%	23,162	121%	LEK
Orca	WHS	5,584			5,556	101%	Unchanged from 2008
Vaquita	WDG	3	2,203	0.14%	574	0.52%	LEK
Pinnipeds	PIN	1,487	10,693	14%	6,987	21%	LEK
Oceanic sea turtles	SP	232			231	100%	Unchanged from 2008
Reef associated turtles	REP	349			347	101%	Unchanged from 2008
Sea birds	SB	4	119	3%	4	100%	Unchanged from 2008
Benthic bacteria	BB	872			872	100%	Unchanged from 2008
Scallops and penshells	BC	1,292			3,567	36%	CPUE
Penaeid shrimp	BD	42,863			13,740	312%	CPUE
Sea cucumbers	BFD	2,453			37,159	7%	CPUE
Sessile invertebrates	BFF	2,461			29,252	8%	Unchanged from 2008
Crabs and lobsters	BFS	18,186	1,089,773	2%	463,305	4%	LEK
Herb. echinoderms	BG	6,086			79,461	8%	Unchanged from 2008
Carn. macrobenthos	BMD	62,021	130,281	48%	81,613	76%	LEK

Table B-2 continued. Biomass in 2008 and 1985 Atlantis models. Biomass (B) present in the Gulf of California as of January 1 (seasonal migrators: SB, WHB, and WHT). B1950 is from Lozano 2006.

Functional group	Code	B_{2008}	B_{1950}	B_{2008}/B_{1950}	B_{1985}	B_{2008}/B_{1985}	B_{1985} parameterization method
Inf. epi. meiobenthos	BML	502,947			502,947	100%	Unchanged from 2008
Bivalves	BMS	27,015	25,918	104%	26,494	102%	LEK
Snails	BO	5,223			39,928	13%	CPUE
Adult blue crab	CEP	47,520			29,912	159%	CPUE
J. blue crab	CEPj	11,880			7,478	159%	(As CEP)
Labile detritus	DL	116,415			116,415	100%	Unchanged from 2008
Refractory detritus	DR	116,415			116,415	100%	Unchanged from 2008
Macroalgae	MA	10,751	78,741	14%	28,389	38%	LEK
Pelagic bacteria	PB	15,788			15,788	100%	Unchanged from 2008
Large phytoplankton	PL	1.3e7			1.3e7	100%	Unchanged from 2008
Small phytoplankton	PS	4.2e6			4.2e6	100%	Unchanged from 2008
Adult blue shrimp	PWN	21,323	107,508	20%	11,663	183%	LEK
J. blue shrimp	PWNj	6,000			3,282	183%	(As PWN)
Seagrass	SG	43,061			43,061	100%	Unchanged from 2008
Jellyfish	ZG	20,979			20,979	100%	Unchanged from 2008
Large zooplankton	ZL	1,097,135			1,097,135	100%	Unchanged from 2008
Squid	ZM	5,584			6,318	88%	CPUE
Small zooplankton	ZS	1,097,135			1,097,135	100%	Unchanged from 2008
Microphytobenthos	MB	567			567	100%	Unchanged from 2008
Carrion detritus	DC	58,207			58,207	100%	Unchanged from 2008

[a]CPUE increased three times from 1985 to present. Not considered representative of biomass change.
[b]Lercari and Chavez 2007.
[c]CPUE increased 20 times from 1985 to present. Not considered representative of biomass change.

Table B-3. Biomass densities ($t \bullet km^{-2}$) by polygon and functional group.

Polygon number	Gulf coney	Extranjero	Leopard grouper	Gulf grouper	Amarillo snapper	Barred pargo	Groupers and snappers	Drums and croakers	Grunts	Herb. fish	Large reef fish	Small reef fish	Small demersal fish
	FBP	**FDB**	**FDC**	**FDD**	**FDE**	**FDF**	**FDM**	**FDO**	**FDP**	**FDS**	**FMM**	**FMN**	**FPL**
0	0.110	0.014	0.009	0.085	0.096	0.050	1.680	0.403	0.336	0.304	3.408	7.383	20.712
1	0.032	0.108	0.009	0.016	0.014	0.009	0.525	2.872	0.281	0.058	0.487	1.405	3.669
2	0.339	1.536	0.029	0.037	0.020	0.023	5.231	1.059	0.753	0.104	10.790	23.726	50.176
3	0.045	0.006	0.004	0.006	0.002	0.004	0.501	4.962	0.111	0.014	0.309	1.466	4.430
4	0.215	0.027	0.019	0.151	0.181	0.089	0.233	11.644	0.310	0.565	0.743	3.542	10.549
5	0.781	0.098	0.241	0.063	0.107	0.036	1.386	0.903	4.141	0.639	2.731	5.921	5.385
6	0.198	0.025	0.154	0.079	0.097	0.043	0.903	0.496	3.010	0.356	1.378	3.105	5.471
7	0.194	2.199	0.017	0.023	0.008	0.014	1.311	24.786	0.419	0.078	1.486	7.186	15.171
8	0.149	0.019	0.013	0.018	0.006	0.011	1.007	19.181	0.322	0.060	0.844	5.560	11.714
9	1.181	24.551	0.101	0.139	0.051	0.084	1.960	193.847	2.548	0.483	11.156	55.218	90.053
10	0.554	0.069	0.047	0.065	0.024	0.039	20.142	6.649	1.194	0.227	15.491	53.501	23.088
11	0.273	0.034	0.023	0.032	0.012	0.019	9.926	3.277	0.588	0.112	7.634	26.366	11.378
12	0.230	0.029	0.020	0.265	0.326	0.156	2.748	0.908	0.559	0.998	4.018	8.790	24.380
13	0.684	0.086	0.973	0.244	0.360	0.154	3.416	1.637	12.375	1.281	4.421	10.619	6.372
14	1.931	41.870	0.165	0.227	0.083	0.137	3.203	314.411	4.166	0.790	18.092	89.583	146.010
15	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1.236	26.788	0.106	0.145	0.053	0.088	2.049	201.158	2.665	0.506	11.575	57.315	93.416
17	0.048	0.006	0.004	0.006	0.002	0.004	0.653	0.171	0.114	0.016	1.665	3.430	9.508
18	0.189	0.024	0.016	0.014	0.005	0.008	0.618	10.324	0.257	0.048	0.653	3.134	9.304
19	0.119	0.015	0.028	0.102	0.126	0.065	0.264	7.521	0.176	0.457	0.411	2.246	5.864
20	0.298	0.037	0.119	0.197	0.269	0.111	0.682	9.659	2.606	0.927	1.105	4.987	6.719
21	0.085	0.011	0.007	0.010	0.004	0.006	2.122	0.365	0.184	0.034	2.396	7.199	13.592
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0.067	0.008	0.006	0.009	0.003	0.005	0.854	3.300	0.163	0.021	1.232	3.187	9.183
24	0.082	0.010	0.007	0.008	0.003	0.005	4.198	3.863	0.144	0.046	3.608	12.453	22.425
25	0.045	0.006	0.073	0.156	0.189	0.097	0.612	10.957	1.553	0.811	0.498	3.048	5.207
26	0.002	0.095	0.009	<0.001	<0.001	0.003	0.070	0.449	0.023	0.037	0.068	0.157	0.433
27	0.011	0.015	0.001	0.001	<0.001	<0.001	0.110	0.320	0.024	0.005	0.191	0.422	1.180
28	0.412	0.052	0.596	0.262	0.367	0.154	2.031	6.189	8.850	1.043	1.976	7.052	5.085
29	0.494	0.062	0.042	0.037	0.014	0.022	6.025	1.958	0.679	0.127	8.931	18.518	51.070
30	0.157	0.020	0.013	0.018	0.007	0.011	4.694	0.721	0.338	0.064	4.410	15.147	24.649
31	0.035	0.004	0.003	0.005	0.002	0.003	0.464	3.022	0.086	0.011	0.299	1.107	3.296
32	0.236	0.030	0.020	0.142	0.170	0.084	2.867	0.937	0.453	0.535	4.258	8.768	24.164

Table B-3 continued. Biomass densities ($t \cdot km^{-2}$) by polygon and functional group.

Polygon number	Gulf coney	Extranjero	Leopard grouper	Gulf grouper	Amarillo snapper	Barred pargo	Groupers and snappers	Drums and croakers	Grunts	Herb. fish	Large reef fish	Small reef fish	Small demersal fish
	FBP	**FDB**	**FDC**	**FDD**	**FDE**	**FDF**	**FDM**	**FDO**	**FDP**	**FDS**	**FMM**	**FMN**	**FPL**
33	0.008	0.018	0.007	0.003	0.001	0.002	0.111	0.135	0.102	0.021	0.246	0.472	1.317
34	0.015	0.007	0.001	0.002	<0.001	<0.001	0.153	0.504	0.033	0.005	0.261	0.601	1.600
35	0.031	0.452	0.242	0.004	0.001	0.061	1.304	0.239	0.075	0.645	3.128	6.158	12.970
36	0.135	0.017	0.012	0.234	0.308	0.138	2.523	0.739	0.412	0.903	2.979	7.668	14.373
37	0.022	0.115	0.103	0.085	0.071	0.047	0.863	0.174	2.718	0.412	2.114	3.432	8.512
38	0.245	0.031	0.796	0.283	0.197	0.230	6.252	43.415	16.794	3.329	1.889	12.308	18.984
39	0.894	0.112	1.085	0.796	1.084	0.470	3.817	27.960	15.510	3.157	6.389	17.362	16.772
40	0.083	0.010	0.116	0.430	0.511	0.241	1.008	23.513	4.817	1.827	0.980	6.508	15.011
41	0.450	0.056	0.040	0.367	0.486	0.217	0.468	19.956	0.536	1.483	1.238	5.865	16.993
42	0.009	0.078	0.056	0.006	0.003	0.015	0.302	0.160	0.280	0.158	0.827	1.308	3.644
43	0.014	0.002	0.079	0.051	0.028	0.022	0.463	1.515	2.750	0.255	1.105	1.622	4.626
44	0.312	0.039	0.028	0.402	0.529	0.237	0.372	22.015	0.481	1.577	1.112	6.396	15.543
45	0.037	0.111	0.010	0.004	0.002	0.004	0.396	0.132	0.082	0.030	1.072	1.921	4.784
46	0.146	0.018	0.014	0.608	0.790	0.359	0.281	28.851	0.452	2.370	1.614	8.114	24.602
47	0.811	0.102	0.072	0.827	1.094	0.489	0.878	40.346	1.230	3.248	2.605	12.385	35.595
48	0.328	0.041	0.407	0.291	0.392	0.172	1.405	9.684	5.688	1.159	1.499	6.195	7.731
49	0.010	0.001	0.023	0.018	0.014	0.008	0.170	1.192	0.887	0.102	0.152	0.401	1.002
50	0.008	0.001	0.047	0.031	0.018	0.014	0.289	0.993	1.657	0.159	0.741	0.967	2.663
51	0.197	0.025	0.018	0.288	0.378	0.170	0.247	15.697	0.315	1.129	0.910	4.509	9.918
52	0.005	0.108	0.021	0.001	<0.001	0.006	0.155	0.940	0.040	0.084	0.132	0.358	1.062
53	1.702	0.213	12.144	2.051	1.990	0.876	49.654	23.527	280.618	20.458	48.016	158.315	72.406
54	0.421	0.053	0.038	0.578	0.761	0.341	0.516	28.484	0.632	2.307	1.295	8.508	17.185
55	0.760	0.095	0.620	0.216	0.298	0.128	2.191	9.217	8.026	1.076	1.881	6.707	7.330
56	0.472	0.059	0.207	0.161	0.156	0.080	1.661	0.730	5.977	0.755	3.057	6.987	16.835
57	0.012	0.002	0.074	0.047	0.025	0.021	0.403	0.536	2.380	0.223	1.077	1.625	4.545
58	0.222	0.028	0.019	0.271	0.357	0.160	2.936	1.152	0.563	1.046	4.396	8.600	23.506
59	0.011	0.001	0.032	0.044	0.048	0.024	0.303	1.372	0.923	0.192	0.450	1.064	2.665
60	0.241	0.030	0.197	0.175	0.232	0.103	0.751	7.937	2.624	0.745	0.772	3.559	5.014
61	0.184	0.023	0.016	0.125	0.165	0.074	1.422	1.498	0.259	0.522	2.064	4.065	11.134
62	0.225	0.028	0.020	0.330	0.434	0.195	2.085	8.842	0.498	1.286	3.200	7.620	18.334
63	0.249	0.031	0.108	0.063	0.067	0.033	0.830	1.683	2.814	0.388	1.267	3.049	6.151
64	5.010	0.628	0.429	0.589	0.216	0.355	93.919	18.528	10.806	2.050	135.508	300.640	839.182
65	0.373	0.047	0.032	0.041	0.022	0.025	3.801	1.108	0.829	0.115	9.151	19.904	55.197

Table B-4. Biomass densities (t • km^{-2}) by polygon and functional group.

Polygon number	Pacific angel shark	Small migratory sharks	Large pelagic sharks	Guitarfish	Skates, rays, sharks	Flatfish	Mojarra	Scorpion-fish	Lanternfish and deep	Totoaba	Large pelagics	Mackerel	Hake
	FPS	FPO	FVB	FVD	FVO	FVS	FVT	FVV	SHB	SHC	SHD	SHP	SHR
0	0.201	9.150	2.452	1.323	3.112	1.695	0.271	0.561	0.496	0.008	1.124	0.438	1.187
1	0.053	2.427	0.651	0.831	0.811	0.443	0.059	0.095	2.378	0.002	0.523	0.235	0.351
2	0.452	20.482	5.506	2.781	7.643	3.581	0.244	1.366	48.234	0.018	2.892	0.981	2.897
3	0.081	3.651	0.991	1.663	1.254	0.718	0.039	0.114	0.207	0.003	0.672	0.732	0.582
4	0.146	7.236	1.796	4.005	2.930	1.696	2.234	0.277	0.542	0.006	0.146	3.278	1.298
5	0.064	2.351	0.713	0.829	1.113	0.567	0.251	0.269	0.878	0.002	0.314	0.135	0.670
6	0.049	2.373	0.601	0.557	0.888	0.496	0.186	0.177	0.216	0.002	0.579	0.144	0.423
7	0.257	11.602	3.131	5.828	4.319	2.444	0.149	0.419	30.639	0.010	1.645	3.181	1.947
8	0.196	8.850	2.388	4.426	3.323	1.855	0.114	0.324	0.602	0.008	1.263	2.447	1.497
9	1.268	57.009	15.400	34.021	25.447	14.201	0.904	2.482	351.015	0.050	1.154	28.479	11.397
10	0.182	7.418	2.121	6.927	2.560	2.945	0.424	1.249	2.231	0.005	9.710	1.202	5.342
11	0.090	3.656	1.045	3.414	1.262	1.451	0.209	0.615	1.099	0.002	4.785	0.592	2.632
12	0.190	9.319	2.338	1.760	3.721	2.058	0.732	0.672	0.581	0.008	2.622	0.810	1.390
13	0.059	2.233	0.661	1.744	1.053	0.777	0.264	0.365	0.836	0.001	1.711	0.220	1.305
14	2.090	94.002	25.387	56.318	41.538	23.551	1.479	4.044	579.212	0.082	1.888	46.555	18.635
15	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1.337	60.142	16.243	36.032	26.576	15.068	0.946	2.587	370.576	0.053	1.208	29.785	11.923
17	0.105	4.799	1.293	0.694	1.499	0.879	0.040	0.261	0.212	0.004	0.258	0.154	0.581
18	0.151	7.440	1.864	3.729	2.632	1.597	0.092	0.246	0.481	0.006	0.712	2.301	1.180
19	0.090	4.437	1.108	2.341	1.654	1.001	1.274	0.154	0.302	0.004	0.265	1.657	0.741
20	0.091	4.434	1.113	2.475	1.845	1.052	1.854	0.217	0.489	0.003	0.157	1.815	0.880
21	0.124	5.648	1.516	1.067	2.167	1.251	0.065	0.381	0.343	0.005	1.113	0.413	0.822
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0.119	5.404	1.449	1.382	1.738	0.919	0.057	0.241	0.302	0.005	0.757	0.373	0.720
24	0.213	9.954	2.603	2.801	3.983	2.250	0.051	0.639	0.269	0.009	2.730	0.930	1.614
25	0.091	4.228	1.105	2.388	1.610	0.959	1.570	0.158	0.127	0.004	0.401	1.378	0.748
26	0.009	0.410	0.107	0.173	0.123	0.078	0.006	0.012	1.738	<0.001	0.079	0.039	0.058
27	0.016	0.727	0.195	0.185	0.226	0.137	0.008	0.032	0.315	<0.001	0.084	0.045	0.092
28	0.061	2.855	0.719	1.680	1.200	0.753	0.927	0.212	0.585	0.002	0.920	0.922	0.767
29	0.423	20.757	5.210	4.331	8.143	5.001	0.241	1.396	1.269	0.017	5.554	2.040	3.076
30	0.224	10.179	2.734	2.066	3.982	2.386	0.120	0.692	0.631	0.009	2.207	0.832	1.511
31	0.066	2.997	0.806	1.226	0.889	0.569	0.030	0.089	0.160	0.003	0.587	0.302	0.404
32	0.202	9.930	2.493	2.119	3.877	2.429	0.502	0.660	0.604	0.008	2.642	0.989	1.465

Table B-4 continued. Biomass densities (t • km^{-2}) by polygon and functional group.

Polygon number	Pacific angel shark	Small migratory sharks	Large pelagic sharks	Guitarfish	Skates, rays, sharks	Flatfish	Mojarra	Scorpion-fish	Lanternfish and deep	Totoaba	Large pelagics	Mackerel	Hake
	FPS	**FPO**	**FVB**	**FVD**	**FVO**	**FVS**	**FVT**	**FVV**	**SHB**	**SHC**	**SHD**	**SHP**	**SHR**
33	0.016	0.752	0.201	0.156	0.232	0.150	0.018	0.036	0.422	<0.001	0.058	0.034	0.092
34	0.020	0.927	0.249	0.232	0.298	0.165	0.011	0.043	0.230	<0.001	0.116	0.059	0.127
35	0.148	6.944	1.821	1.160	2.114	1.336	0.027	0.353	15.160	0.007	0.356	0.177	0.839
36	0.122	6.012	1.504	1.333	2.372	1.485	0.544	0.391	0.335	0.005	1.589	0.601	0.884
37	0.088	4.104	1.074	0.780	1.397	0.876	0.281	0.235	3.785	0.004	0.502	0.192	0.549
38	0.431	20.058	5.264	9.266	6.088	3.811	3.672	0.595	0.568	0.019	4.258	2.060	2.844
39	0.237	11.499	2.867	6.797	4.583	2.986	4.512	0.602	1.452	0.008	1.763	4.413	2.474
40	0.289	13.502	3.525	7.665	4.879	3.239	6.178	0.440	0.380	0.012	1.239	4.375	2.392
41	0.271	13.494	3.520	8.060	5.208	3.566	6.297	0.459	0.897	0.011	0.304	5.968	2.369
42	0.044	2.047	0.537	0.405	0.633	0.416	0.053	0.099	2.719	0.002	0.120	0.064	0.254
43	0.068	3.188	0.835	0.942	0.950	0.621	0.581	0.126	0.065	0.003	0.360	0.181	0.407
44	0.252	12.514	3.115	7.319	4.668	3.126	5.239	0.412	0.790	0.010	0.230	5.241	2.087
45	0.049	2.226	0.598	0.342	0.721	0.385	0.027	0.135	1.653	0.002	0.182	0.083	0.317
46	0.436	20.413	5.319	13.360	8.240	5.715	11.515	0.758	0.664	0.019	0.182	9.658	4.183
47	0.611	30.444	7.536	17.998	11.479	7.988	15.254	1.041	2.063	0.024	0.618	13.137	5.453
48	0.120	5.935	1.465	3.676	2.369	1.646	2.429	0.284	0.601	0.005	0.673	2.461	1.240
49	0.023	1.085	0.284	0.546	0.337	0.233	0.388	0.033	0.030	0.001	0.195	0.155	0.170
50	0.040	1.871	0.490	0.576	0.561	0.376	0.342	0.073	0.038	0.002	0.209	0.109	0.241
51	0.164	8.120	2.014	4.790	3.010	2.045	3.367	0.266	0.510	0.007	0.147	3.387	1.349
52	0.022	1.043	0.273	0.448	0.308	0.209	0.016	0.030	2.056	<0.001	0.186	0.100	0.145
53	0.770	32.618	9.110	24.550	8.468	10.992	3.888	3.560	6.856	0.024	2.983	2.256	16.419
54	0.297	14.786	3.651	9.078	6.077	4.033	6.487	0.558	0.995	0.012	0.300	6.648	2.630
55	0.073	3.551	1.624	3.158	1.588	1.570	1.705	0.219	0.542	0.002	1.018	1.516	0.883
56	0.165	7.858	2.002	1.115	2.722	1.412	0.524	0.486	0.541	0.007	0.947	0.339	0.939
57	0.059	2.761	0.723	0.663	0.842	0.570	0.318	0.124	0.055	0.003	0.205	0.110	0.345
58	0.208	10.267	2.565	2.521	4.026	2.695	0.989	0.626	0.574	0.009	2.704	1.085	1.517
59	0.037	1.720	0.450	0.727	0.608	0.427	0.422	0.077	0.046	0.002	0.270	0.289	0.281
60	0.073	3.629	1.064	2.550	1.469	1.131	1.603	0.159	0.304	0.003	0.358	1.589	0.721
61	0.096	4.729	1.327	1.369	1.888	1.361	0.555	0.286	0.265	0.004	1.280	0.560	0.701
62	0.195	9.632	2.395	3.720	3.775	2.668	1.916	0.496	0.581	0.008	1.867	2.090	1.536
63	0.070	3.370	0.851	0.848	1.160	0.619	0.421	0.188	0.286	0.003	0.546	0.218	0.496
64	5.944	268.304	72.315	48.411	128.416	57.687	3.836	23.543	20.187	0.238	97.666	22.123	48.342
65	0.552	25.124	6.742	3.152	8.417	4.053	0.268	1.503	1.412	0.023	1.556	0.889	3.190

Table B-5. Biomass densities (t • km^{-2}) by polygon and functional group.

Polygon number	Small pelagics	Mysticeti	Odonto-cetae	Orca	Vaquita	Pinnipeds	Oceanic sea turtles	Reef associated turtles	Sea birds	Benthic bacteria	Scallops and penshells	Penaeid shrimp	Sea cucumbers
	SSK	**WHB**	**WHT**	**WHS**	**WDG**	**PIN**	**SP**	**REP**	**SB**	**BB**	**BC**	**BD**	**BFD**
0	4.340	2.887	1.017	0.203	0	0.002	0.013	0.013	<0.001	0.037	0	2.376	0
1	1.282	0.853	0.300	0.060	0	<0.001	0.004	0.004	<0.001	0.011	0	0.625	0
2	11.251	7.043	2.642	0.526	0	0.015	0.031	0.033	<0.001	0.089	0	5.272	0
3	1.548	1.415	0.414	0.082	0	0	0.005	0.005	<0.001	0.018	0	0.954	0
4	7.669	3.157	1.551	0.309	0	0.069	0.014	0.019	<0.001	0.040	0	1.646	0
5	8.377	1.629	1.964	0.391	0	0.118	0.002	0.024	<0.001	0.021	0.317	0.439	0.718
6	3.961	1.029	0.573	0.114	0	0.050	0.001	0.007	<0.001	0.013	0.042	0.535	0.068
7	6.633	4.735	2.366	0.471	0	0.051	0.020	0.029	<0.001	0.060	0	2.972	0
8	5.098	0	1.818	0.362	0	0.039	0.015	0.023	<0.001	0.046	0	2.265	0
9	41.654	0	14.493	2.885	0	0.317	0.121	0.180	0.002	0.351	0	14.284	0
10	19.523	12.989	6.793	1.352	0	0.149	0.057	0.084	<0.001	0.164	0.808	1.358	0.767
11	9.621	6.401	3.348	0.666	0	0.073	0.028	0.042	<0.001	0.081	0.398	0.669	0.378
12	8.212	3.380	1.661	0.331	0	0.074	0.015	0.021	<0.001	0.043	0	2.197	0
13	9.693	0	2.275	0.453	0	0.138	0.004	0.028	<0.001	0.040	0.390	0.393	0.696
14	68.109	0	23.698	4.717	0	0.519	0.199	0.294	0.003	0.574	0	23.573	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
16	43.576	125.628	15.162	3.018	0	0.332	0.127	0.188	0.002	0.367	0	15.082	0
17	1.642	6.122	0.485	0.097	0	0.004	0.005	0.006	<0.001	0.018	0	1.268	0
18	6.775	12.435	1.265	0.252	0	0.055	0.012	0.016	<0.001	0.036	0	1.742	0
19	4.255	1.802	0.794	0.158	0	0.034	0.008	0.010	<0.001	0.023	0	1.029	0
20	9.717	0	1.430	0.285	0	0.110	0.008	0.018	<0.001	0.027	0.102	0.961	0.231
21	3.003	0	1.024	0.204	0	0.022	0.009	0.013	<0.001	0.025	0	1.455	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	2.642	7.588	0.605	0.120	0	<0.001	0.008	0.008	<0.001	0.022	0	1.401	0
24	3.318	0	1.365	0.272	0	0.053	0.007	0.017	<0.001	0.050	0	2.637	0
25	2.099	1.819	0.637	0.127	0	0.031	0.003	0.008	<0.001	0.023	0	1.115	0
26	0.119	0	0.024	0.005	0	<0.001	<0.001	<0.001	<0.001	0.002	0	0.109	0
27	0.358	0.224	0.084	0.017	0	<0.001	<0.001	0.001	<0.001	0.003	0	0.189	0
28	9.674	0	1.564	0.311	0	0.115	0.007	0.019	<0.001	0.024	0.073	0.524	0.069
29	17.751	7.480	3.328	0.663	0	0.141	0.032	0.041	<0.001	0.095	0	4.908	0
30	5.523	3.674	1.922	0.383	0	0.042	0.016	0.024	<0.001	0.047	0	2.618	0
31	1.344	0.983	0.321	0.064	0	0	0.004	0.004	<0.001	0.012	0	0.781	0
32	8.457	0	1.586	0.316	0	0.067	0.015	0.020	<0.001	0.045	0	2.350	0

Table B-5 continued. Biomass densities (t • km^{-2}) by polygon and functional group.

Polygon number	Small pelagics	Mysticeti	Odontocetae	Orca	Vaquita	Pinnipeds	Oceanic sea turtles	Reef associated turtles	Sea birds	Benthic bacteria	Scallops and penshells	Penaeid shrimp	Sea cucumbers
	SSK	WHB	WHT	WHS	WDG	PIN	SP	REP	SB	BB	BC	BD	BFD
33	0.335	0.223	0.077	0.015	0	<0.001	<0.001	<0.001	<0.001	0.003	0	0.196	0
34	0.493	0.309	0.116	0.023	0	<0.001	0.001	0.001	<0.001	0.004	0.004	0.239	0.009
35	1.724	0	0.293	0.058	0	<0.001	0.004	0.004	<0.001	0.026	0	1.860	0
36	8.105	2.150	0.851	0.169	0	0.069	0.009	0.011	<0.001	0.027	0	1.429	0
37	1.485	1.335	0.273	0.054	<0.001	0.010	0.002	0.003	<0.001	0.017	0	1.097	0
38	8.753	6.914	2.302	0.458	0	0.110	0.011	0.029	<0.001	0.088	0	5.324	0
39	27.230	0	3.859	0.768	0	0.291	0.023	0.048	<0.001	0.076	0.129	2.417	0.117
40	6.472	0	0.761	0.151	0	0.017	0.010	0.009	<0.001	0.074	0	3.567	0
41	29.560	0	1.796	0.357	0	0.233	0.023	0.022	<0.001	0.073	0	3.106	0
42	0.523	0	0.085	0.017	0	0	0.001	0.001	<0.001	0.008	0	0.548	0
43	1.101	0	0.129	0.026	<0.001	0.003	0.002	0.002	<0.001	0.013	0	0.853	0
44	19.525	5.074	1.582	0.315	0	0.140	0.020	0.020	<0.001	0.064	0	2.910	0
45	1.231	0	0.289	0.058	0	0.002	0.003	0.004	<0.001	0.010	0.019	0.573	0.037
46	11.317	0	1.331	0.265	0	0.029	0.017	0.017	<0.001	0.129	0	5.354	0
47	50.654	0	4.133	0.823	0	0.363	0.053	0.051	<0.001	0.168	0	6.979	0
48	12.491	0	1.839	0.366	0	0.139	0.012	0.023	<0.001	0.038	0.049	1.286	0.043
49	0.490	0	0.087	0.017	<0.001	0.003	<0.001	0.001	<0.001	0.005	0.010	0.287	0.022
50	0.651	0	0.077	0.015	0.001	0.002	<0.001	<0.001	<0.001	0.007	0	0.501	0
51	12.279	0	1.022	0.204	0	0.087	0.013	0.013	<0.001	0.042	0	1.889	0
52	0.297	0	0.048	0.010	0	0	<0.001	<0.001	<0.001	0.004	0	0.278	0
53	60.009	0	20.879	4.156	0	0.457	0.175	0.259	0.003	0.505	17.337	6.888	39.118
54	23.934	0	3.340	0.665	0	0.256	0.025	0.041	<0.001	0.081	0	3.395	0
55	42.063	0	1.537	0.306	0	0.437	0.008	0.019	<0.001	0.027	0.075	0.705	0.061
56	7.606	0	1.083	0.216	0	0.081	0.003	0.013	<0.001	0.029	0	1.890	0
57	0.934	0	0.110	0.022	<0.001	0.002	0.001	0.001	<0.001	0.011	0	0.739	0
58	13.807	0	1.150	0.229	0	0.098	0.015	0.014	<0.001	0.047	0	2.439	0
59	0.769	0	0.101	0.020	<0.001	0.003	0.001	0.001	<0.001	0.009	0.003	0.456	0.002
60	14.225	0	0.961	0.191	<0.001	0.147	0.007	0.012	<0.001	0.022	0.024	0.807	0.020
61	12.651	0	0.531	0.106	<0.001	0.108	0.007	0.007	<0.001	0.022	0	1.123	0
62	13.982	0	1.164	0.232	<0.001	0.099	0.015	0.014	<0.001	0.047	0	2.258	0
63	4.021	1.207	0.573	0.114	0	0.043	0.002	0.007	<0.001	0.015	0.056	0.782	0.128
64	176.683	117.548	61.474	12.237	0	1.346	0.515	0.764	0.008	1.488	0	67.911	0
65	12.392	0	2.910	0.579	0	0.016	0.034	0.036	<0.001	0.098	0	6.516	0

Table B-6. Biomass densities ($t \bullet km^{-2}$) by polygon and functional group.

Polygon number	Sessile invertebrates	Crabs and lobsters	Herb. echino-derms	Carn. macro-benthos	Inf.-epif. meio-benthos	Bivalves	Snails	Adult blue crab	J. blue crab	Labile detritus	Refractory detritus	Macro-algae	Pelagic bacteria
	BFF	BFS	BG	BMD	BML	BMS	BO	CEP	CEP	DL	DR	MA	PB
0	0	0.496	0	3.481	14.024	0	0	2.634	0.658	4.601	4.601	0.267	0.037
1	<0.001	0.076	0	0.396	1.661	0	0.003	0.693	0.173	1.359	1.359	0	0.011
2	0	1.324	0	8.960	37.394	0	0	5.844	1.461	11.222	11.222	0	0.089
3	<0.001	0.210	0	0.009	5.188	0	0.007	1.057	0.264	2.254	2.254	0	0.018
4	<0.001	1.433	0	0	40.476	0	0.016	1.825	0.456	5.030	5.030	0.584	0.040
5	0.372	0.017	0.507	0.343	<0.001	4.846	0.775	0.487	0.122	2.596	2.596	0.603	0.021
6	0.103	0.332	0.332	2.195	9.344	0.969	0.234	0.593	0.148	1.639	1.639	0.381	0.013
7	<0.001	1.118	0	0.022	29.867	0	0.024	3.295	0.824	7.545	7.545	0.876	0.060
8	<0.001	0.883	0	0.017	23.596	0	0.019	2.512	0.628	5.798	5.798	0.673	0.046
9	<0.001	12.567	0	0	355.013	0	0.144	15.836	3.959	44.155	44.155	10.255	0.351
10	3.611	6.496	11.478	41.326	183.509	28.753	7.389	1.506	0.376	20.696	20.696	4.806	0.164
11	1.780	3.201	5.657	20.366	90.436	14.170	3.641	0.742	0.185	10.199	10.199	2.369	0.081
12	0	1.741	0	10.950	49.186	0	0	2.436	0.609	5.386	5.386	1.251	0.043
13	0.888	1.042	2.373	6.861	29.073	8.829	1.900	0.436	0.109	5.056	5.056	1.174	0.040
14	<0.001	20.235	0	0	571.627	0	0.232	26.134	6.533	72.199	72.199	16.768	0.574
15	0	0	0	0	0	0	0	0	0	0	0	0	0
16	<0.001	12.946	0	0	365.723	0	0.149	16.720	4.180	46.193	46.193	10.728	0.367
17	0	0	0	0.258	0	0	0	1.406	0.351	2.251	2.251	0	0.018
18	<0.001	0.867	0	0.009	23.813	0	0.015	1.931	0.483	4.572	4.572	0	0.036
19	<0.001	0.669	0	0.003	18.695	0	0.009	1.140	0.285	2.871	2.871	0.667	0.023
20	0.119	0.763	0.161	0.093	21.398	1.561	0.272	1.065	0.266	3.409	3.409	0.792	0.027
21	0	0.658	0	4.320	18.580	0	0	1.613	0.403	3.183	3.183	0.739	0.025
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	<0.001	0.025	0	0.177	<0.001	0	0.005	1.553	0.388	2.790	2.790	0	0.022
24	<0.001	1.478	0	9.266	41.051	0	0.005	2.924	0.731	6.252	6.252	1.452	0.050
25	<0.001	0.539	0	0.005	14.753	0	0.009	1.237	0.309	2.898	2.898	0.673	0.023
26	<0.001	0.004	0	0.004	<0.001	0	<0.001	0.121	0.030	0.224	0.224	0	0.002
27	<0.001	0.002	0	0.027	<0.001	0	<0.001	0.209	0.052	0.357	0.357	0	0.003
28	0.317	0.862	0.991	3.455	24.353	2.708	0.676	0.581	0.145	2.971	2.971	0.690	0.024
29	0	3.680	0	23.434	103.970	0	0	5.442	1.360	11.918	11.918	1.384	0.095
30	0	1.352	0	8.796	38.179	0	0	2.903	0.726	5.855	5.855	1.360	0.047
31	<0.001	0.025	0	0.026	<0.001	0	0.004	0.866	0.216	1.566	1.566	0	0.012
32	0	1.750	0	11.142	49.445	0	0	2.605	0.651	7.381	7.381	0.659	0.045

Table B-6 continued. Biomass densities (t • km^{-2}) by polygon and functional group.

Polygon number	Sessile invertebrates	Crabs and lobsters	Herb. echino-derms	Carn. macro-benthos	Inf.-epif. meio-benthos	Bivalves	Snails	Adult blue crab	J. blue crab	Labile detritus	Refractory detritus	Macro-algae	Pelagic bacteria
	BFF	BFS	BG	BMD	BML	BMS	BO	CEP	CEP	DL	DR	MA	PB
33	<0.001	<0.001	0	0.041	<0.001	0	<0.001	0.217	0.054	0.462	0.462	0	0.003
34	0.005	0.004	0.006	0.036	<0.001	0.058	0.010	0.265	0.066	0.492	0.492	0.029	0.004
35	0	0	0	0.422	0	0	0	2.062	0.516	4.224	4.224	0.189	0.026
36	0	1.052	0	6.695	29.719	0	0	1.584	0.396	4.453	4.453	0.398	0.027
37	0	0.245	0	1.731	6.916	0	0	1.216	0.304	2.765	2.765	0.247	0.017
38	<0.001	0.197	0	0.061	<0.001	0	0.032	5.902	1.476	11.017	11.017	1.279	0.088
39	0.584	2.663	1.704	6.115	75.233	4.777	1.216	2.680	0.670	9.584	9.584	1.113	0.076
40	<0.001	1.678	0	0.017	45.829	0	0.025	3.955	0.989	9.268	9.268	0	0.074
41	<0.001	2.416	0	0	68.252	0	0.025	3.444	0.861	11.934	11.934	0	0.073
42	<0.001	<0.001	0	0.127	<0.001	0	<0.001	0.607	0.152	1.280	1.280	0	0.008
43	<0.001	0.013	0	0.121	<0.001	0	0.002	0.946	0.236	2.050	2.050	0	0.013
44	<0.001	2.149	0	0	60.699	0	0.024	3.226	0.806	8.085	8.085	0	0.064
45	0.036	0.033	0.085	0.343	0.914	0.365	0.076	0.635	0.159	1.228	1.228	0	0.010
46	<0.001	4.173	0	0	117.890	0	0.041	5.935	1.484	16.207	16.207	0	0.129
47	<0.001	5.440	0	0	153.688	0	0.054	7.738	1.934	21.128	21.128	0	0.168
48	0.237	1.272	0.618	2.245	35.936	1.831	0.484	1.426	0.356	4.803	4.803	1.115	0.038
49	0.010	0.029	0.014	0.011	0.548	0.145	0.021	0.319	0.080	0.659	0.659	0.077	0.005
50	<0.001	0.008	0	0.073	<0.001	0	0.001	0.555	0.139	1.213	1.213	0	0.007
51	<0.001	1.381	0	0	38.998	0	0.015	2.095	0.524	6.795	6.795	0	0.042
52	<0.001	0.009	0	0.013	<0.001	0	0.001	0.308	0.077	0.560	0.560	0	0.004
53	13.627	0.476	22.315	13.933	<0.001	264.806	27.010	7.637	1.909	63.612	63.612	14.774	0.505
54	<0.001	2.595	0	0	73.315	0	0.026	3.764	0.941	10.189	10.189	2.366	0.081
55	0.340	0.925	0.861	3.139	26.123	2.839	0.673	0.781	0.195	3.421	3.421	0.795	0.027
56	0	0.390	0	2.756	11.022	0	0	2.095	0.524	3.637	3.637	0	0.029
57	<0.001	0.004	0	0.151	<0.001	0	<0.001	0.820	0.205	1.739	1.739	0	0.011
58	0	1.790	0	11.394	50.573	0	0	2.704	0.676	7.641	7.641	0	0.047
59	0.013	0.177	0.035	0.680	4.856	0.112	0.027	0.505	0.126	1.090	1.090	0.063	0.009
60	0.108	0.730	0.282	1.034	20.633	0.966	0.218	0.894	0.224	3.632	3.632	0.649	0.022
61	0	0.825	0	5.254	23.319	0	0	1.245	0.311	2.715	2.715	0	0.022
62	<0.001	1.705	0	7.637	48.163	0	0.005	2.503	0.626	5.952	5.952	0	0.047
63	0.066	0.137	0.091	0.907	3.499	0.862	0.132	0.867	0.217	1.923	1.923	0	0.015
64	0	66.276	0	403.887	1,872.228	0	0	75.289	18.822	187.293	187.293	0	1.488
65	0	0	0	1.484	0	0	0	7.223	1.806	12.360	12.360	0	0.098

Table B-7. Biomass densities (t • km^{-2}) by polygon and functional group.

Polygon number	Large phytoplankton	Small phyto-plankton	Adult blue shrimp	J. blue shrimp	Seagrass	Jellyfish	Large zoo-plankton	Squid	Small zoo-plankton	Micro-phyto-benthos	Carrion detritus
	PL	PS	PWN	PWN	SG	ZG	ZL	ZM	ZS	MB	DC
0	0.037	0.037	1.065	0.300	0	0.880	13.876	0.203	13.876	0.041	2.300
1	0.011	0.011	0.278	0.078	0	0.260	4.098	0.060	4.098	0	0.679
2	0.089	0.089	2.615	0.736	0	2.146	33.848	0.526	33.848	0	5.611
3	0.018	0.018	0.429	0.121	0	0.431	6.799	0.082	6.799	0	1.127
4	0.040	0.040	1.002	0.282	0	0.962	105.086	0.309	105.086	0.045	2.515
5	0.021	0.021	0.381	0.107	0	0.496	7.830	0.391	7.830	0.023	1.298
6	0.013	0.013	0.304	0.086	8.580	0.313	34.238	0.114	34.238	0.015	0.819
7	0.060	0.060	1.478	0.416	0	1.442	22.755	0.471	22.755	0	3.772
8	0.046	0.046	1.137	0.320	0	1.109	17.488	0.362	17.488	0	2.899
9	0.351	0.351	8.707	2.450	0	8.442	133.178	2.885	133.178	0	22.078
10	0.164	0.164	0.876	0.246	0	3.957	62.421	1.352	62.421	0	10.348
11	0.081	0.081	0.432	0.121	0	1.950	30.762	0.666	30.762	0.091	5.100
12	0.043	0.043	1.273	0.358	0	1.030	112.525	0.331	112.525	0.048	2.693
13	0.040	0.040	0.360	0.101	0	0.967	15.251	0.453	15.251	0.045	2.528
14	0.574	0.574	14.212	3.999	0	13.804	217.762	4.717	217.762	0	36.100
15	0	0	0	0	0	0	0	0	0	0	0
16	0.367	0.367	9.093	2.559	0	8.832	139.323	3.018	139.323	0	23.096
17	0.018	0.018	0.513	0.144	0	0.430	6.789	0.097	6.789	0	1.126
18	0.036	0.036	0.900	0.253	0	0.874	95.519	0.252	95.519	0	2.286
19	0.023	0.023	0.566	0.159	5.368	0.549	59.983	0.158	59.983	0.026	1.436
20	0.027	0.027	0.631	0.178	17.847	0.652	71.222	0.285	71.222	0.030	1.705
21	0.025	0.025	0.741	0.209	0	0.609	9.601	0.204	9.601	0	1.592
22	0	0	0	0	0	0	0	0	0	0	0
23	0.022	0.022	0.595	0.167	0	0.533	8.415	0.120	8.415	0	1.395
24	0.050	0.050	1.363	0.384	0	1.195	18.857	0.272	18.857	0	3.126
25	0.023	0.023	0.551	0.155	0	0.554	8.740	0.127	8.740	0.026	1.449
26	0.002	0.002	0.042	0.012	0	0.043	0.675	0.005	0.675	0	0.112
27	0.003	0.003	0.077	0.022	0	0.068	1.078	0.017	1.078	0	0.179
28	0.024	0.024	0.411	0.116	12.963	0.568	62.078	0.311	62.078	0.027	1.486
29	0.095	0.095	2.786	0.784	0	2.279	248.985	0.663	248.985	0.107	5.959
30	0.047	0.047	1.362	0.383	0	1.119	17.658	0.383	17.658	0	2.927
31	0.012	0.012	0.304	0.086	0	0.299	4.725	0.064	4.725	0	0.783
32	0.045	0.045	1.327	0.373	0	1.086	118.614	0.316	118.614	0.051	3.690

Table B-7 continued. Biomass densities (t • km^{-2}) by polygon and functional group.

Polygon number	Large phytoplankton	Small phyto-plankton	Adult blue shrimp	J. blue shrimp	Seagrass	Jellyfish	Large zoo-plankton	Squid	Small zoo-plankton	Micro-phyto-benthos	Carrion detritus
	PL	PS	PWN	PWN	SG	ZG	ZL	ZM	ZS	MB	DC
33	0.003	0.003	0.079	0.022	0	0.068	1.072	0.015	1.072	0	0.231
34	0.004	0.004	0.102	0.029	0	0.094	1.484	0.023	1.484	0	0.246
35	0.026	0.026	0.723	0.204	0	0.621	9.799	0.058	9.799	0	2.112
36	0.027	0.027	0.811	0.228	1.601	0.655	71.563	0.169	71.563	0.031	2.227
37	0.017	0.017	0.478	0.134	0	0.407	6.415	0.054	6.415	0.019	1.382
38	0.088	0.088	2.083	0.586	0	2.106	33.229	0.458	33.229	0.099	5.508
39	0.076	0.076	1.568	0.441	0	1.832	200.232	0.768	200.232	0.086	4.792
40	0.074	0.074	1.669	0.470	0	1.772	27.953	0.151	27.953	0.083	4.634
41	0.073	0.073	1.782	0.501	10.012	1.755	191.776	0.357	191.776	0.082	5.967
42	0.008	0.008	0.216	0.061	0	0.188	2.971	0.017	2.971	0	0.640
43	0.013	0.013	0.325	0.091	0	0.301	4.756	0.026	4.756	0.014	1.025
44	0.064	0.064	1.597	0.449	3.779	1.546	168.914	0.315	168.914	0.072	4.043
45	0.010	0.010	0.247	0.069	0	0.235	3.702	0.058	3.702	0	0.614
46	0.129	0.129	2.819	0.793	0	3.099	48.881	0.265	48.881	0.145	8.103
47	0.168	0.168	3.928	1.105	23.042	4.039	441.385	0.823	441.385	0.189	10.564
48	0.038	0.038	0.811	0.228	0	0.918	100.339	0.366	100.339	0.043	2.401
49	0.005	0.005	0.115	0.032	0	0.126	1.988	0.017	1.988	0.006	0.330
50	0.007	0.007	0.192	0.054	0	0.178	2.814	0.015	2.814	0.008	0.606
51	0.042	0.042	1.030	0.290	2.443	0.999	109.198	0.204	109.198	0	3.398
52	0.004	0.004	0.105	0.030	0	0.107	1.690	0.010	1.690	0	0.280
53	0.505	0.505	2.897	0.815	0	12.162	1,328.946	4.156	1,328.946	0.569	31.806
54	0.081	0.081	2.079	0.585	11.112	1.948	212.852	0.665	212.852	0.091	5.094
55	0.027	0.027	0.543	0.153	3.731	0.654	71.472	0.306	71.472	0.031	1.711
56	0.029	0.029	0.932	0.262	0	0.695	75.988	0.216	75.988	0.033	1.819
57	0.011	0.011	0.288	0.081	0	0.256	4.034	0.022	4.034	0.012	0.869
58	0.047	0.047	1.377	0.388	6.410	1.124	122.789	0.229	122.789	0.053	3.820
59	0.009	0.009	0.208	0.058	0	0.208	3.288	0.020	3.288	0.010	0.545
60	0.022	0.022	0.503	0.141	3.047	0.534	58.361	0.191	58.361	0.025	1.816
61	0.022	0.022	0.646	0.182	1.269	0.519	56.711	0.106	56.711	0.024	1.357
62	0.047	0.047	1.292	0.363	0	1.138	124.349	0.232	124.349	0.053	2.976
63	0.015	0.015	0.397	0.112	0	0.368	40.172	0.114	40.172	0.017	0.961
64	1.488	1.488	43.937	12.363	0	35.808	564.901	12.237	564.901	0	93.647
65	0.098	0.098	2.880	0.810	0	2.363	37.280	0.579	37.280	0	6.180

Appendix C: Field Work Protocols

[Editor's note: This appendix provides three protocols: a trawl and longline sampling protocol, a fish stomach sampling protocol, and a community interview questionnaire. Minor modification was applied to each for inclusion in this technical memorandum. Original versions of the three are available from Cameron Ainsworth, e-mail ainsworth@marine.usf.edu].

Trawl and Longline Sampling Protocol for Atlantis Gulf of California EBFM Modeling Project. PANGAS Training Protocol Version 2.0 (February 2008)

Introduction

This protocol describes trawl and longline fisheries surveys designed to assess the relative abundance and absolute biomass of nearshore demersal fish species in the upper Gulf of California. This protocol identifies 15 work site locations extending along a 300 km section of the north and northeastern Gulf of California. These work sites are located on either side of Puerto Peñasco; they represent preselected sampling areas determined using a semirandom method. The areas will be sampled once in the winter of 2008 (February/March), and once in the summer of 2008 (August/September). This protocol also provides trawl and longline survey designs for use at each work site. Trawls and longlines are deployed along the shoreline in an alternating pattern at intervals that are preselected using a semirandom method. The figures and tables in this protocol provide work site selection maps, site-specific survey designs, and data entry forms.

Objectives and Audience

The objective of this training protocol is to train Centro Intercultural de Estudios de Desiertos y Oceanos (CEDO) staff (especially training facilitators) in trawl and longline sampling techniques to be used in the Atlantis Gulf of California EBFM (ecosystem-based fisheries management) modeling project. The data collected using this procedure will help set the abundance parameters in a food web computer model for the marine ecosystem of the upper gulf.

Materials

Materials required for this protocol include:

1. Printouts of the figures and tables,
2. Motorized panga,
3. Hand-drawn 16-ft (4.9-m) otter trawl,

4. Longlines with approximately 20 hooks (No. 5) and bait,
5. Global positioning system (GPS) navigation equipment, and
6. Acoustic depth finder

Protocol

The general procedure is as follows:

- Choose a work site for the day using the preselected work sites in Figure C-1 and Table C-1.
- Arrive at the work site approximately 2 hours prior to high tide.
- Bait the longline while on shore and load the panga with the research equipment (trawl and longlines).
- Proceed out on the panga beyond the surf zone and deploy the longline perpendicular to the shore. The longline will be deployed in shallow, medium, or deep water according to Figure C-2 and Figure C-3.
- Record the start and end depths of the longline on the data sheets in Figure C-4 and Figure C-5.
- Conduct trawls 1 through 4 using preselected spacing in Figure C-2 and Figure C-3. During sorting, record the data on the data sheets.
- Retrieve longline and record the data on the data sheets.

Choosing a work site

Fifteen sites will be sampled altogether in the trawl and longline sampling project. Sampling at these sites will be repeated in spring (beginning March) and summer (beginning August). One or more sites can be sampled in a work day. Seven sites lay to the west of Puerto Peñasco and eight sites lay to the east. The sites have been preselected in Figure C-1 and Table C-1 using a random method. From the starting point at Puerto Peñasco, travel west or east to one of the preselected sites. Figure C-1 shows the approximate locations of the sampling sites to the west and east of Puerto Peñasco, respectively. The coordinates of each site are provided in Table C-1 for use with GPS navigation equipment. On average, the sites are approximately 20 km apart.

Sampling should be conducted during neap tides. Plan to arrive at the work site approximately 2 hours before high tide. After arriving at the work site, determine whether the area is suitable for trawling: for example, if the area has a soft bottom and easy access to the beach. If the site is suitable, deploy the trawl and longline at this location. If the site is not suitable, then continue away from Puerto Peñasco until a suitable area is located. Make a note in the data entry form (Figure C-4 and Figure C-5) describing why the initial site was rejected; also, record the distance traveled from the initial site before a suitable location was found.

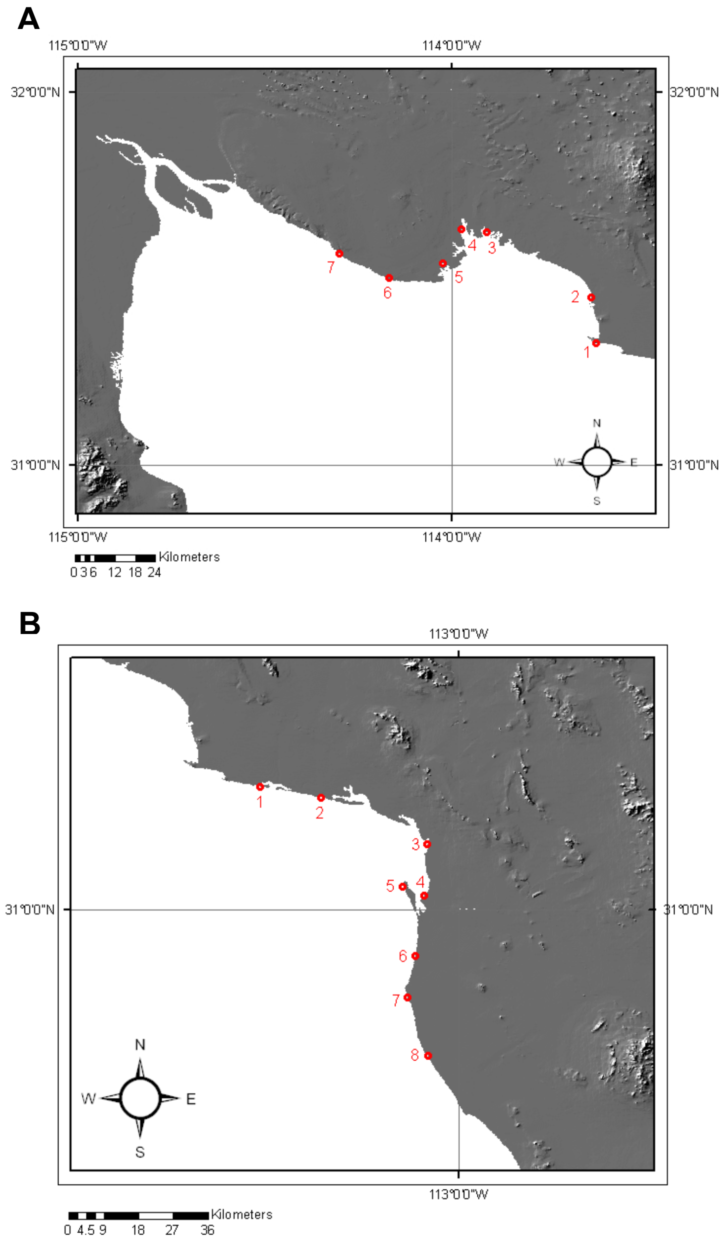


Figure C-1. Randomly selected work sites. Seven sites are west of Puerto Peñasco (panel A); eight are east of Puerto Peñasco (panel B). The work sites correspond to coordinates in Table C-1.

Table C-1. Coordinates for randomly selected work sites. Site numbers correspond to Figure C-1 for west of Puerto Peñasco (panel A) and east of Puerto Peñasco (panel B).

	Site No.	**Distance to Pto. Peñasco (km)**	**Latitude**	**Longitude**
West of Puerto Peñasco	1	7	31.32650	–113.61385
	2	28	31.46741	–113.63261
	3	56	31.62867	–113.85844
	4	78	31.66244	–113.99853
	5	105	31.54504	–114.05345
	6	128	31.50111	–114.17546
	7	141	31.56018	–114.29479
East of Puerto Peñasco	1	10	31.28536	–113.46520
	2	27	31.25567	–113.31935
	3	48	31.19335	–113.12090
	4	76	31.03815	–113.05042
	5	97	31.04891	–113.12579
	6	115	30.89058	–113.10033
	7	129	30.77408	–113.11126
	8	142	30.66092	–113.07491

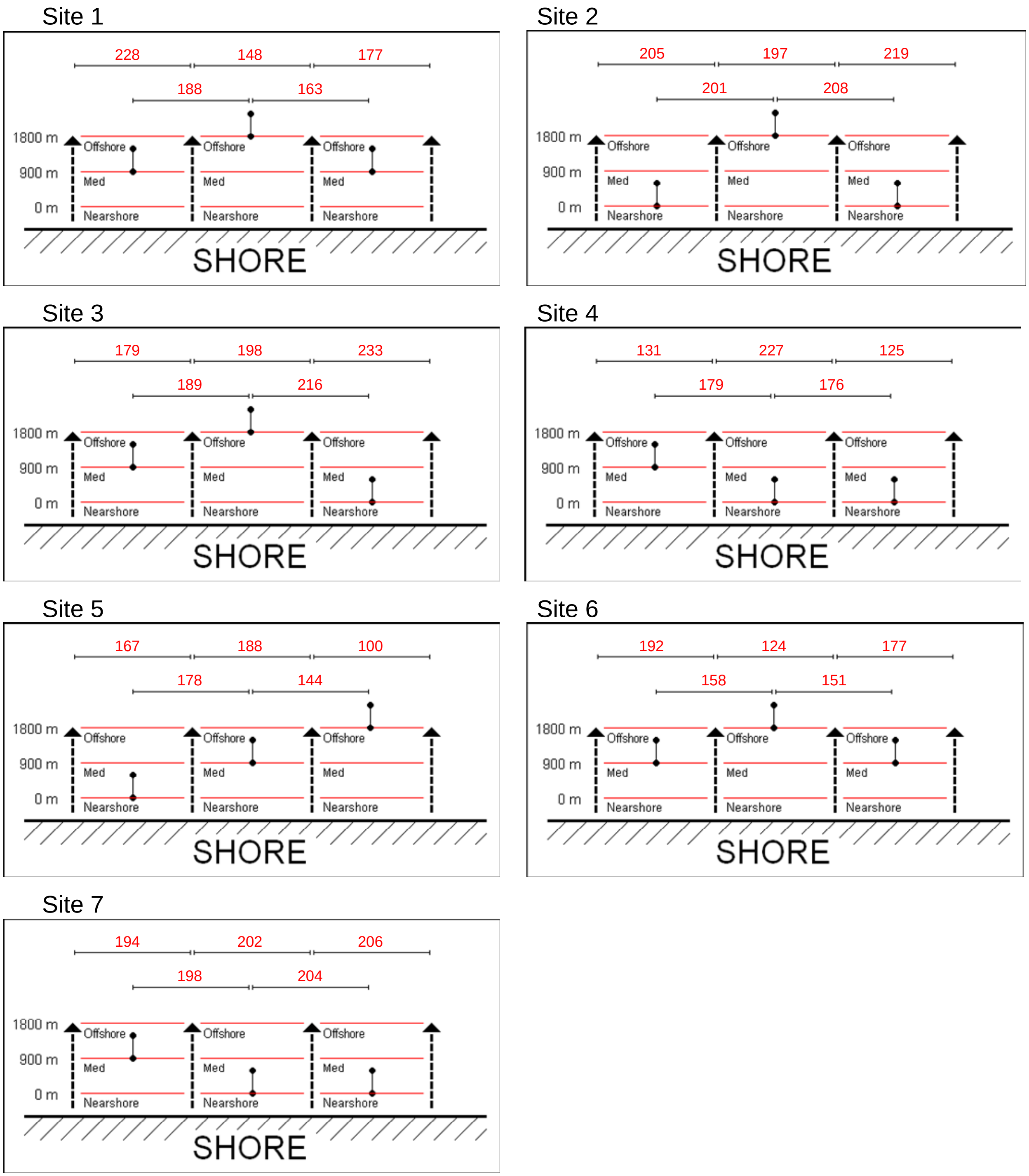


Figure C-2. Trawl and longline survey design at site level west of Puerto Peñasco.

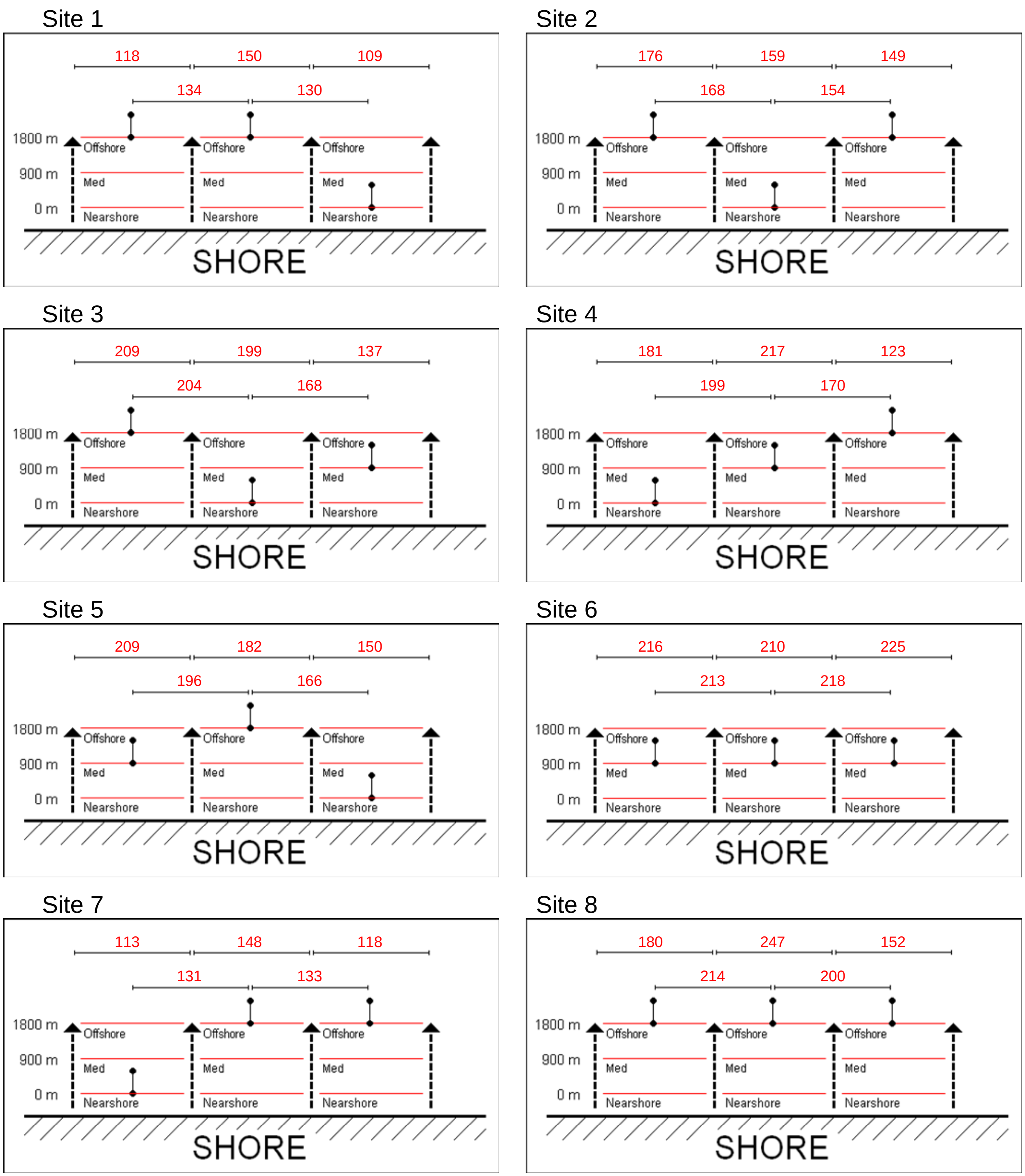


Figure C-3. Trawl and longline survey design at site level east of Puerto Peñasco.

Section 1: Site selection

Site No: ____________

Substrate composition: ____

Current and tide conditions: ____

Section 2: Longline results

Longline 1

Type of bait: ____________

Time in: ____________ Time out: ____________

Nearshore depth: ____________

Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	

Other species ____

Longline 2

Type of bait: ____________

Time in: ____________ Time out: ____________

Nearshore depth: ____________

Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	

Other species ____

Longline 3

Type of bait: ____________

Time in: ____________ Time out: ____________

Nearshore depth: ____________

Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	
Species:		Size (cm):		Number:	

Other species ____

Additional notes:

Figure C-4. Data entry form (page 1 of 2).

Section 3: Trawl results

Trawl 1

Duration of trawl (min): ______
Speed of boat: ______
Maximum depth: ______

Species:	Size (cm):	Number:
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______

Other species ______________________________

Trawl 2

Duration of trawl (min): ______
Speed of boat: ______
Maximum depth: ______

Species:	Size (cm):	Number:
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______

Other species ______________________________

Trawl 3

Duration of trawl (min): ______
Speed of boat: ______
Maximum depth: ______

Species:	Size (cm):	Number:
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______

Other species ______________________________

Trawl 4

Duration of trawl (min): ______
Speed of boat: ______
Maximum depth: ______

Species:	Size (cm):	Number:
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______

Other species ______________________________

Trawl 5

Duration of trawl (min): ______
Speed of boat: ______
Maximum depth: ______

Species:	Size (cm):	Number:
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______
Species: ______	Size (cm): ______	Number: ______

Other species ______________________________

Additional notes:

Figure C-5. Data entry form (page 2 of 2).

General survey design

Consult Figure C-2 and Figure C-3 (survey design) for the trawl and longline survey design that is to be used at each day's worksite. Figure C-6 below shows a generic example of the survey design used in this protocol. Distances in this figure represent randomly selected values. At each site, four trawl tows will be conducted. The tows will be spaced apart at random distances, labeled Distance 1, Distance 2, and Distance 3 in Figure C-6. These distances are provided in Figure C-2 and Figure C-3. Tows are for 20 minutes at 3 knots (5.5 km/h); total distance covered then will be approximately 1,800 m.

Longlines will be deployed halfway between trawl transects (three longlines in total). Longlines should be deployed perpendicular to shore. The distance between the longlines is represented by Distance A and Distance B in Figure C-6. The distance from shore at which the longline is deployed is also chosen randomly and presented in Figure C-2 and Figure C-3. Distance from shore is given as offshore, medium, or nearshore; however, longlines should never be placed any deeper than 12 m (at the nearshore end). Offshore longlines will therefore be anchored at 1,800 m from shore or 12 m depth, medium longlines will be anchored 900 m from shore or at 12 m depth, and nearshore longlines will be anchored close to shore.

All distances provided are approximate. The researchers should only perform a trawl tow if the substrate is suitable (e.g., soft bottom and free of obstructions). Similarly, they should only deploy the longline if the area is suitable. If the area for a tow or longline is not suitable, then the researchers should continue further down the shoreline until a suitable area is found. In this case, the gaps between trawl tows may be larger than the distances described in Figure C-2 and Figure C-3. Make a note in the data entry form describing why the tow or longline site was rejected.

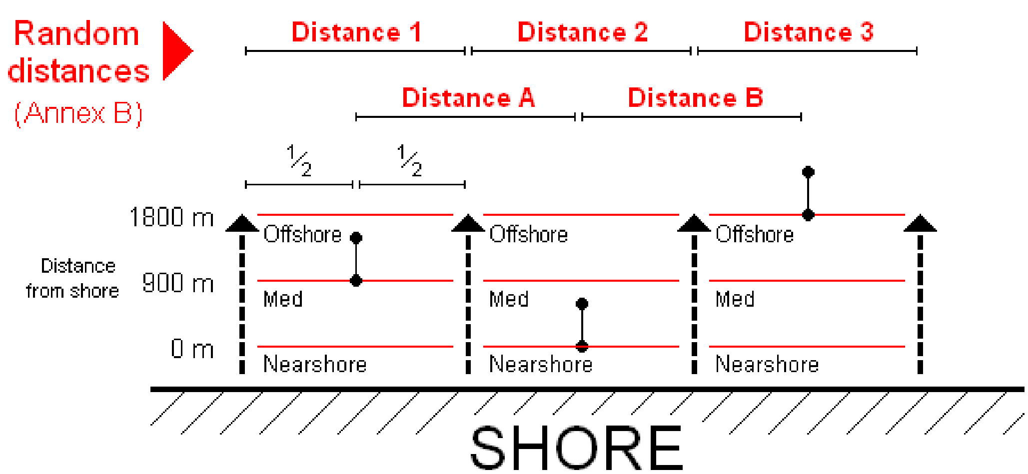


Figure C-6. Trawl and longline survey design. Three longlines and four trawl tows are conducted at each work site. Random distances are provided in Figure C-2 and Figure C-3. Trawl tows (broken arrows) are spaced apart at random distances (distances 1, 2, and 3). Longlines (dumbbells) are placed mid distance between trawl tows. Distance between longlines is provided by Distance A and Distance B.

Deploying longlines

After baiting the longline on shore, load all research equipment on the panga, and proceed out beyond the surf zone. Deploy all three longlines at the depth described in Figure C-2 and Figure C-3. Soak time for the longlines should be approximately 2 hours. Record the time that the longline was put into the water on the data entry form. Using the acoustic sounder, estimate the actual depth of the longline at the nearshore end and record this information on the data entry sheet (Figure C-4 and Figure C-5). While the longlines are soaking, proceed with the trawl tows.

Conducting trawl tows

After the longlines are deployed, begin trawl tows 1 through 4. The relative position of the longlines can be used to judge where the trawl tow should begin. Deploy the trawl in shallow water, just beyond the surf zone, and travel out to sea perpendicular to shore as shown in Figure C-7. The duration of the trawl should be no longer than 20 minutes. If the depth exceeds 12 m, then turn left or right to follow the 12 m contour (Figure C-7).

Depending on the density of fish encountered in the first tow, it may be necessary to reduce the tow time in order to ensure that the trawl is not completely full of fish by the end of the tow. Record the duration of each trawl on the data entry form in minutes (Figure C-4 and Figure C-5), as well as the speed of the boat and the maximum depth of the trawl as estimated using the acoustic sounder.

After retrieving the trawl, sort the catch and enter the data onto the data entry form. Data to be entered include species caught, size (cm), and number of fish caught. Record the size of fish to within 5 cm. Use several rows for the same species of fish if multiple size classes are encountered. Species can be identified to the species or family level using common names. Return fish to the sea as soon as possible after retrieving the trawl in order to minimize the number of fish killed. If fish are taken for further study (e.g., stomach samples), make a note of the number of fish, the species, and the trawl number. Proceed to the next trawl area and repeat the procedure until all four trawl tows are complete.

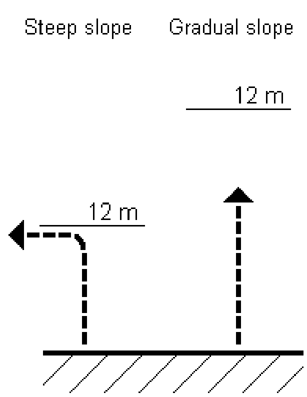


Figure C-7. Trawl depth should not exceed 12 m. Follow 12 m contour for area with steep slopes.

Retrieving longlines

After the trawl tows are complete, retrieve the first longline, sort the catch, and enter the data onto the data entry form. Record the time when the longline was removed from the water. Also record the type of bait used, the longline depth at the nearshore end, species caught, and size and number of fish caught. Record the size of fish to within 5 cm. Use several rows for the same species of fish if multiple size classes are encountered. Species can be identified to the species or family level using common names. Return fish to the sea as soon as possible to minimize the number of fish killed. If fish are taken for further study (e.g., stomach samples), make a note of the number of fish, the species, and the longline number. Retrieve the second and third longlines using the same procedure, then return to shore.

Dissemination

Return the completed data entry forms (Figure C-4 and Figure C-5) to Cameron Ainsworth at the Northwest Fisheries Science Center (currrently at ainsworth@marine.usf.edu).

Version History

Version 1: Draft (January 2008)

Version 2: Final (February 2008)

- Protocol revised after pilot study conducted by CEDO and NOAA in February 2008.
- Trawl pattern changed from semicircular to straight design because nearshore depth rarely exceeds 12 m maximum.
- Tow time increased from 10 minutes to 20 minutes because catch rates are low.
- Number of trawls per site reduced from five to four because of longer tow times.
- Number of hooks on longline increased from 10 to 20 because of quick rigging time.
- Size of hooks is reduced from No. 7 to No. 5 to catch a wider variety of fish sizes.
- Total number of sites sampled is reduced from 30 to 15, with sampling done twice per year (March and August) to represent seasonal patterns of abundance.
- Average distance between trawls is increased (now between 100–250 m).
- Longlines are equidistant between trawl tows to simplify survey design.

Version 3: Spanish translation (February 2008)

Guidelines for Adjusting this Protocol

Field staff and training facilitators are encouraged to send proposed changes to the author (ainsworth@marine.usf.edu). Such proposed changes and improvements will be entered in the version history under planned improvements. After review, we will redistribute the revised protocol.

Fish Stomach Sampling Protocol for Atlantis Gulf of California EBFM Modeling Project. PANGAS Training Protocol Version 1.0 (December 2007)

Introduction

This protocol consists of two parts. Part 1, specimen collection, is conducted in the field. It consists of obtaining fish stomachs from fishers at fishery landing sites or from fish markets, preserving them in numbered jars, and recording information about the fish being sampled (e.g., type of fish, size). Part 2, stomach content analysis, is conducted in the laboratory. The preserved stomachs are dissected. The stomach contents are identified, sorted, and weighed. The purpose of this stomach sampling study is to determine the diet (in percent composition) of the common commercial fish species captured in the upper Gulf of California and common bycatch fish species.

Objectives and Audience

The objective of this training protocol is to train CEDO and Comunidad y Biodiversidad (COBI) staff (especially training facilitators) in fish stomach sampling techniques used in the Atlantis Gulf of California EBFM modeling project. The purpose of sampling is to identify and quantify the prey items of commercial fish to the species or family level. The stomach content data collected using this procedure will help to parameterize a food web computer model for the marine ecosystem of the upper Gulf of California. All fish species caught in the area are of interest.

Part 1: Specimen Collection Materials and Protocol

Materials

Materials required for this specimen collection protocol include:

- Several printouts of the form in Figure C-8,
- Ruler,
- Scalpel or sharp knife,
- Dissecting scissors,
- Dissecting tray, and
- Approximately 20 plastic jars (numbered).

Protocol

The general procedure is as follows:

- Purchase fish from market or fishers, or pay fishers nominal fee to remove stomach.

#	Specimen	Length (cm) (TL or FL)	Gape size (mm)	Area caught	Habitat type	Gear type used	Bait	Jar #
1	Juvenile grouper	7.5 (TL)	8	Bahia San Jorge	Shallow reef	Gillnet	none	1
2	Adult parrotfish	65	66	Puerto Libertad	Lagoon	Trap	none	2
3	Adult Wahoo	98	15	Puerto Lobos	Ocean	Handline	anchovy	3
					-			

Figure C-8. Specimen collection form.

- Record pertinent information on the predator being studied, the gear type used, and the area of capture.
- Measure the total or fork length, weight, gape size, and maturity stage of the fish specimen.
- Remove the stomach into a plastic jar and freeze promptly.

Specimen collection—Purchase fish directly from fishers or from the fish market. Alternatively, pay fishers a fee to remove the stomach (this is preferable for valuable commercial species). The fees may vary depending on sizes, numbers, and the location of where fish are collected. Record pertinent information on the Figure C-8 sheet, such as common species name or fish family (e.g., grouper, trigger fish); also indicate adult or juvenile stage if known. Record gear type used to catch the fish, type of bait used, and area where the fish was caught (i.e., place name if possible and also habitat type, such as reef, estuary, open water or deep water).

Measuring fish length and weight—Using a ruler, measure the total length or fork length of the fish specimen. Total length (TL) is a measure from the tip of the mouth with the jaws closed to the tip of the tail, with the tail fin lobes compressed to give the maximum possible length. Fork length (FL) is a measure from the tip of the mouth with the jaws closed to the central part of the tail fin (Figure C-9). Fork length should be used for species with long tail fins. Specify which measurement you are taking by recording TL or FL on the sheet (Figure C-8).

Gape size and maturity stage—To determine the gape size (mouth size), measure the length of the premaxilla bone (upper jaw bone) from the tip (foremost point) to the far end of the hinge (Figure C-10) for teleost fish. Gape size should be measured to the nearest millimeter or to the nearest eighth of an inch. Record the maturity stage of the fish (juvenile or adult) if known. Do not measure gape size for non-teleost fish such as sharks or rays or eels.

Stomach removal—Using scissors or a scalpel, cut the fish open from the anus to the bottom of the jaw. Remove the stomach by cutting the esophagus near the anterior end; gently pull to disconnect it from the intestines. The stomach is a U-shaped balloon-like organ; it will vary in appearance with species and contents.

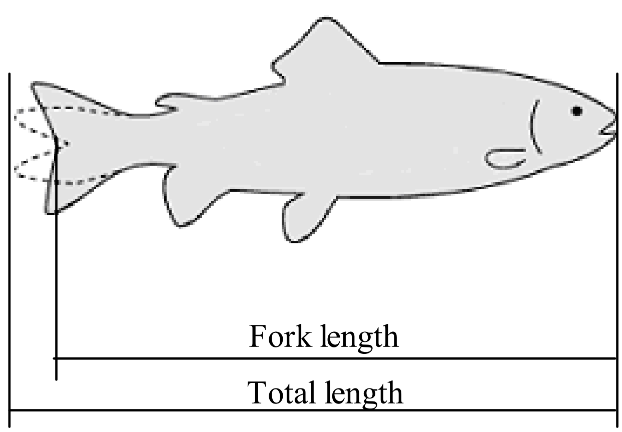


Figure C-9. Fork length and total length for fish specimen.

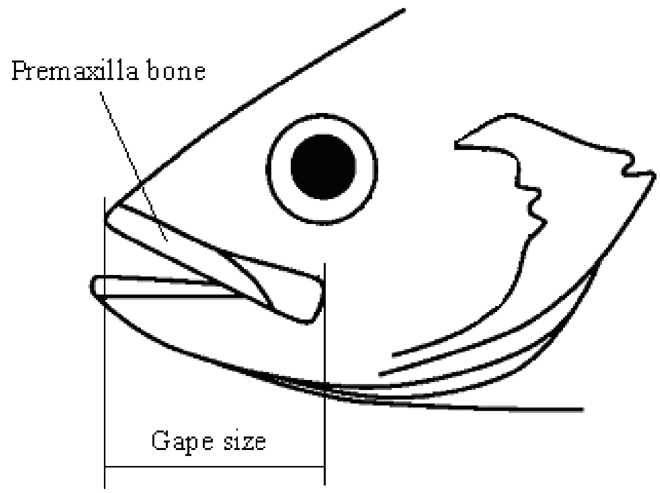


Figure C-10. Gape size of fish specimen. Measure the premaxilla bone from the tip of the nose to the end of the hinge.

Preserving stomachs—Place the fish stomach in a numbered jar and record the jar number on the form in Figure C-8. Stomachs from the same species or family can be combined in the same specimen jar. A variety of jar sizes may be required depending on the types of fish being sampled. Jars of 200–500 ml capacity should accommodate most fish stomachs, but 1,000 ml jars or larger should be available for larger fish specimens such as billfish. Seal jar for later laboratory analysis; freeze as soon as possible, preferably within 2 hours.

Other notes

In cases where the available catch is large, fish should be selected randomly from among species and size classes listed in Figure C-8. No more than 20 stomachs need be sampled for any particular species or maturity stage. For example, no more than 20 adult groupers or 20 juvenile snappers should be sampled. A variety of fish is important; try to sample each commercial species available.

Part 2: Stomach Content Analysis Materials and Protocol

Materials

Materials required for stomach content analysis include:

- Specimen jars containing preserved stomachs,
- Several printouts of the form in Figure C-11,
- Scalpel or a sharp knife,
- Dissecting scissors,
- Dissecting tray,
- Tweezers or forceps,

Specimen jar #: ____________________

Predator sampled: ____________________

Whole stomach weight: ____________________

Number of stomachs ____________________

	Plastic tray #	Prey categories	Column A Idenity of prey (species or family)	Column B Weight of plastic tray (g)	Column C Weight of prey items (g)
Inverts.	1	Shrimp / prawn			
	2	Squid / cuttlefish			
	3	Jellyfish			
	4	Worms			
	5	Octopus			
	6	Sponges / tunicates			
	7	Bivalves			
	8	Snails			
	9	Starfish / sea cucumbers			
	10	Small crab (< 5 cm)			
	11	Large crab (> 5 cm)			
Fish	12	Small pelagic fish (e.g. sardine) (< 10 cm)			
	13	Large pelagic fish (e.g.mackerel, tuna) (> 10 cm)			
	14	Small reef fish (e.g. wrasse) (<10cm)			
	15	Large reef fish (e.g. grouper)			
	16	Small demersal fish			
	17	Large demersal fish			
	18	Unidentified fish			

Figure C-11. Laboratory analysis form.

- Paper towel,
- Electronic or mechanical scale, and
- Disposable plastic trays labeled by prey groups listed in Figure C-11.

Protocol

General procedure is as follows:

- Thaw samples and remove stomach from the specimen jar.
- Weigh whole stomach.
- Label plastic trays by prey groups listed in Figure C-11.
- Dissect stomachs and blot the contents dry using paper towel.
- Sort contents into appropriate plastic trays.
- Weigh contents of each tray and record result in the laboratory analysis form (Figure C-11).

Stomach dissection—Thaw samples and remove the stomach from the specimen jar; weigh it whole. Record the data in the laboratory analysis form. Using scissors or a scalpel, cut open the stomach and remove all of the contents to a dissecting tray. Sort through the stomach contents and identify each prey item, at least to the family level. Enter the description in column A. Do not consider material found in the intestines, as it will be too digested to accurately identify. Please note that for the purposes of the ecosystem model, it is important that we identify every prey item present in the stomach; however, we do not require a high degree of precision (family level is sufficient).

Weighing stomach contents—Blot the stomach contents using a paper towel to remove excess liquid. Record the empty weight of each plastic tray first (column B), and then sort the stomach contents to the appropriately labeled trays. Weigh each specimen tray and subtract the weight of the empty tray to determine the wet weight of stomach contents. Report results in column C. The objective will be to determine a percent diet composition for each commercial fish.

If any prey items cannot be identified, place them into the jar labeled "unidentified fish" or into the jar labeled "unidentified other" if it cannot be determined whether the prey item is a fish. Multiple fish stomachs may be sampled before weighing the specimen trays provided that they are in the same taxonomic category as reported in the Figure C-8 form (e.g., they are all juvenile groupers). In this case, also record the total number of stomachs sampled on the form in Figure C-11.

Other notes

The numerical quantity of prey items is not important, only the identity of prey items and the total wet weight. Dissection and sorting stomach contents should be done immediately after thawing to avoid decomposition of stomach contents. Figure C-12 provides a completed example of the form.

Version History

Version 1.0: Draft (December 2007)

Planned improvements

- Peer review
- Translation to Spanish

Guidelines for Adjusting this Protocol

CEDO or COBI field staff and training facilitators are encouraged to send proposed changes to the author (ainsworth@marine.usf.edu). Such proposed changes and improvements will be entered in the version history under "Planned improvements." After review, we will redistribute the revised protocol.

Specimen jar #: ***1***

Predator sampled: ***Juvenile grouper***

Whole stomach weight: ***102 g***

Number of stomachs ***1***

	Plastic tray #	Prey categories	Column A Idenity of prey (species or family)	Column B Weight of plastic tray (g)	Column C Weight of prey items (g)
Inverts.	1	Shrimp / prawn		***2.1 g***	
	2	Squid / cuttlefish		***2.4 g***	
	3	Jellyfish		***2.1 g***	
	4	Worms	***Polychaetes*** ***Tube worms***	***2 g***	***20 g***
	5	Octopus		***2.1 g***	
	6	Sponges / tunicates		***2.2 g***	
	7	Bivalves		***2.1 g***	
	8	Snails	***limpet*** ***whelk***	***2.2 g***	***22.2 g***
	9	Starfish / sea cucumbers		***2.1 g***	
	10	Small crab (< 5 cm)	***unident.***	***2.4 g***	***15.5 g***
	11	Large crab (> 5 cm)		***2.1 g***	
Fish	12	Small pelagic fish (e.g. sardine) (< 10 cm)		***2.1 g***	
	13	Large pelagic fish (e.g.mackerel, tuna) (> 10 cm)		***2.1 g***	
	14	Small reef fish (e.g. wrasse) (<10cm)	***fusilier*** ***unident.***	***2.1 g***	***18.4 g***
	15	Large reef fish (e.g. grouper)		***2.1 g***	
	16	Small demersal fish		***2.1 g***	
	17	Large demersal fish		***2.2 g***	
	18	Unidentified fish		***2.3 g***	

Figure C-12. Example of completed laboratory analysis form.

Community Interview Questionnaire for Fishers in Support of Atlantis Gulf of California EBFM Modeling Project

Contact: Cameron Ainsworth
Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, WA 98112
Work: +1 206 860 3289 Mobile: +1 604 908 2665
cameron.ainsworth@noaa.gov (currently at ainsworth@marine.usf.edu)

Fisher demographic information

Main species fished: ______________________________

Main gear types used: ______________________________

Number of months spent fishing each year: __________________

Number of years experience fishing: __________________

AGE: ☐ < 20 ☐ 20–30 ☐ 30–40 ☐ 40–50 ☐ 50–60 ☐ > 60

Please answer the questions on the form provided (Table C-2). Leave anything blank if you do not know.

- Abundance change: For each decade (1950, 1960, 1970, 1980, 1990, and 2000) indicate the relative abundance of the fish or animal. Enter plus (+) for periods of high abundance, zero (0) for periods of medium abundance, and minus (–) for periods of low abundance.
- Has there been a large increase in the price for this fish (i.e., has a recent market developed?). If yes, indicate the approximate year.
- Has there been a major depletion or extirpation of this species? Yes or no.
- Has the fish or animal become smaller? Yes or no.

Table C-2. Questionnaire for fishers.

Group name (English)	Group name (Español)	Composition	Abundance change? (–/0/+) 1950	1960	1970	1980	1990	2000	Major price increase? (what year)	Major depletion? (Y/N)	Are fish smaller? (Y/N)
Groupers											
Gulf coney	Baqueta	*Epinephelus acanthistius*									
Extranjero	Extranjero	*Paralabrax auroguttatus, Paralabrax loro*									
Leopard grouper	Cabrilla sardinera	*Mycteroperca rosacea*									
Gulf grouper	Baya	*Mycteroperca jordani*									
Other groupers	Mero	Serranidae									
Snappers											
Amarillo snapper	Pargo amarilo	*Lutjanus argentiventris*									
Barred pargo	Pargo coconaco	*Hoplopagrus guentherii*									
Other snappers	Pargo	Lutjanidae									
Reef fish											
Drums and croakers	Chano	Sciaenidae									
Grunts	Chicharro	Haemulidae									
Parrotfish	Peces loro	Scaridae									
Surgeonfish	Peces cirujano	Acanthuridae									
Large reef fish	Peces arrecifales mayores	E.g., wrasses (Labridae), triggerfishes (Balistidae)									
Small reef fish	Peces arrecifales menores	E.g., pufferfish (Tetraodontidae) (botete), gobies (Gobiidae)									
Elasmobranchs											
Pacific angel shark	Angelito	*Squatina californica*									
Small migratory sharks	Tiburón tripa	Smooth-hounds (*Mustelus* spp.)									
Large pelagic sharks	Tiburones pelágicos grandes	Selachimorpha									
Guitarfish	Guitarra	Rhinobatidae									
Skates, rays, and sharks	Rayas, mantas y tiburones	E.g., butterfly ray, diamond stingray									
Bottomfish											
Flatfish	Lenguado	E.g., flounders (Pleuronectidae, Bothidae, Paralichthyidae)									
Mojarra	Mojarra	Gerreidae									
Scorpionfish	Peces escorpión	Scorpaenidae, Triglidae									
Lanternfish and deep	Mictófidos	Myctophidae									
Pelagic fish											
Totoaba	Totoaba	*Totoaba macdonaldi*									
Large pelagics	Pelágicos mayores	E.g., Sphyraenidae, Carangidae, Istiophoridae									
Mackerel	Sierra	Scombridae									
Hake	Merluza	Merlucciidae									
Small pelagics	Pelágicos menores	E.g., herring/sardines (Clupeidae), anchovy (Engraulidae)									
Invertebrates											
Crabs and lobsters	Jaiba y langosta	*Callinectes bellicosus, C. arcuatus*, Order Decapoda									
Scallops and penshells	Callo y almejas	E.g., *Spondylus calcifer, S. princeps, Pteria sterna*									
Other bivalves	Almejas, mejillones, ostras	Bivalvia									
Shrimp	Camarón	Penaeidae									
Sea cucumbers	Pepino de mar	Holothuroidea									
Urchins	Pilluelo	Echinodermata									
Snails	Caracol	Gastropoda									
Squid	Calamar	Teuthoidea									
Mammals											
Mysticeti	Ballena (misticetos)	E.g., fin whale (*Balaenoptera physalus*), blue whale (*B. musculus*), humpback whale (*Megaptera novaeangliae*)									
Toothed whales	Ballena (odontocetos)	E.g., sperm whales (*Physeter macrocephalus*), pilot whales (*Globicephala macrorhynchus*), orcas (*Orcinus orca*)									
Dolphins	Delfin	Dolphins (*Delhinus capensis, D. delphis, Tursiops truncatus, Lagenorhynchus obliquidens*)									
Vaquita	Vaquita	*Phocoena sinus*									
Pinnipeds	Pinípedos	Seals, California sea lions									
Other											
Turtles	Tortugas	Testudines									
Sea birds	Aves marinas										

Appendix D: Model Dynamics

This appendix contains the following figures:

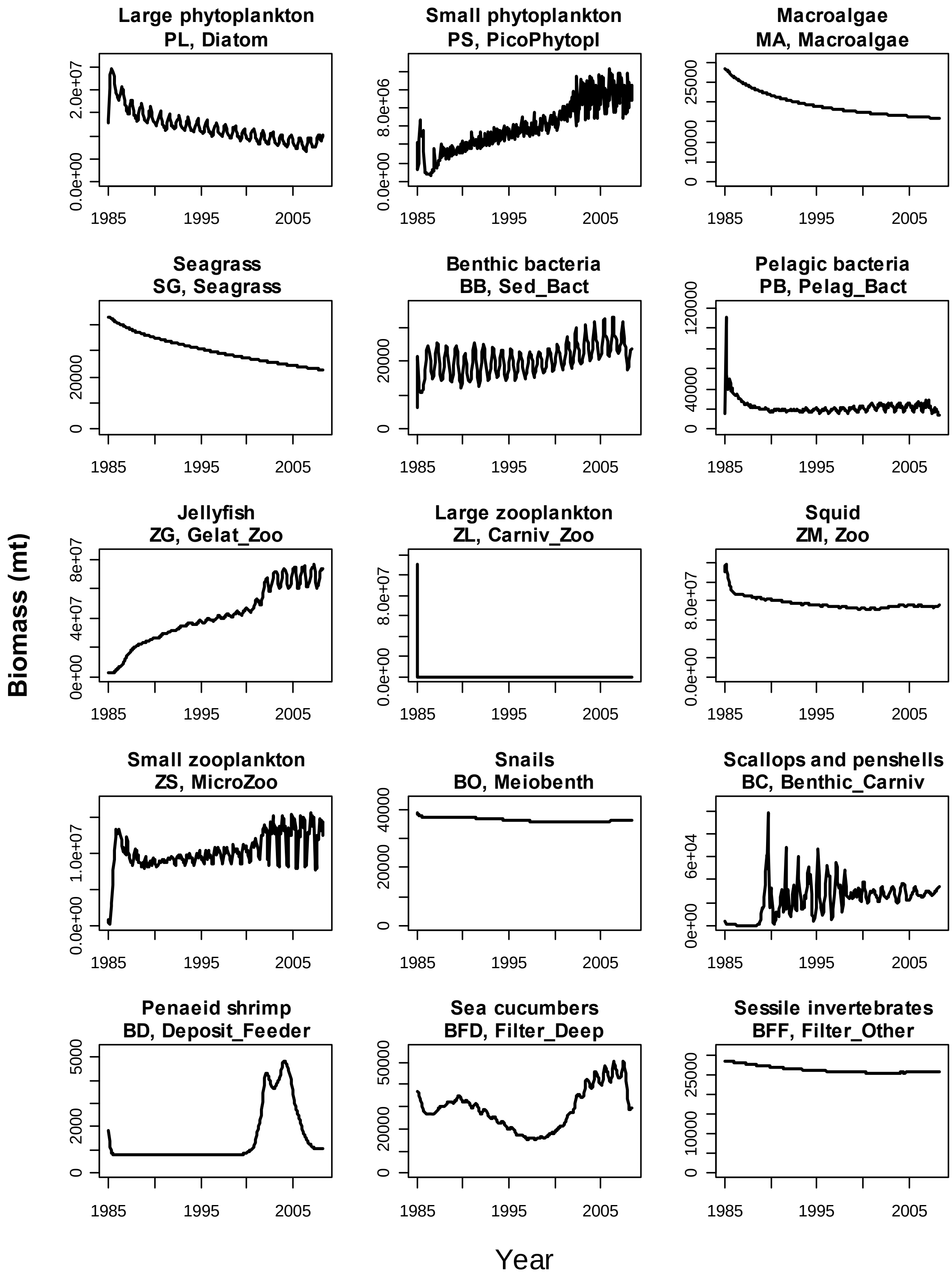


Figure D-1. Biomass dynamics 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for 15 functional groups. Labels show Gulf of California Atlantis model name (e.g., large phytoplankton), short code (e.g., PL) and NetCDF code (e.g., Diatom).

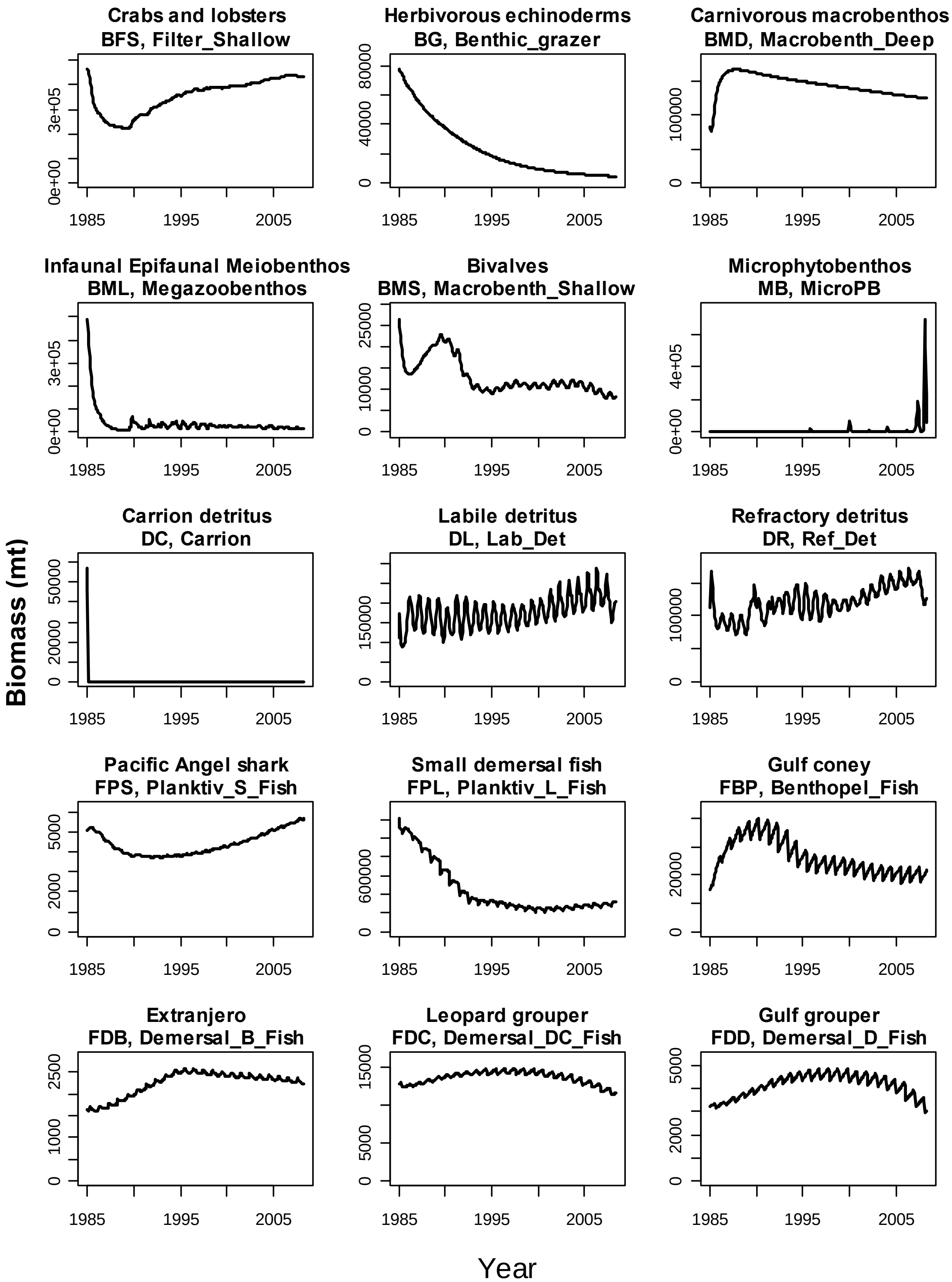


Figure D-2. Biomass dynamics 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for 15 functional groups. Labels show Gulf of California Atlantis model name (e.g., crabs and lobsters), short code (e.g., BFS) and NetCDF code (e.g., Filter_Shallow).

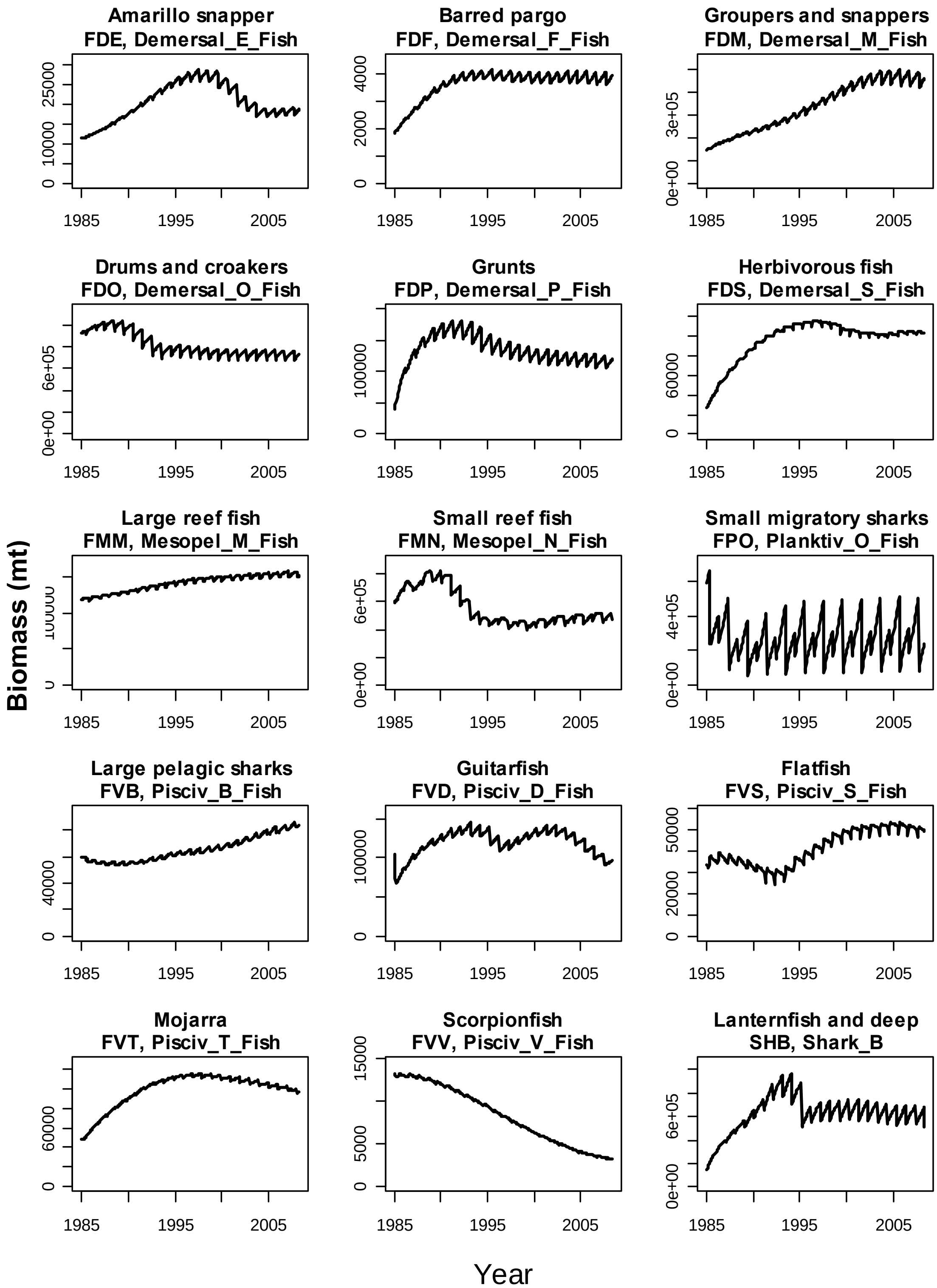


Figure D-3. Biomass dynamics 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for 15 functional groups. Labels show Gulf of California Atlantis model name (e.g., Amarillo snapper), short code (e.g., FDE) and NetCDF code (e.g., Demersal_E_Fish).

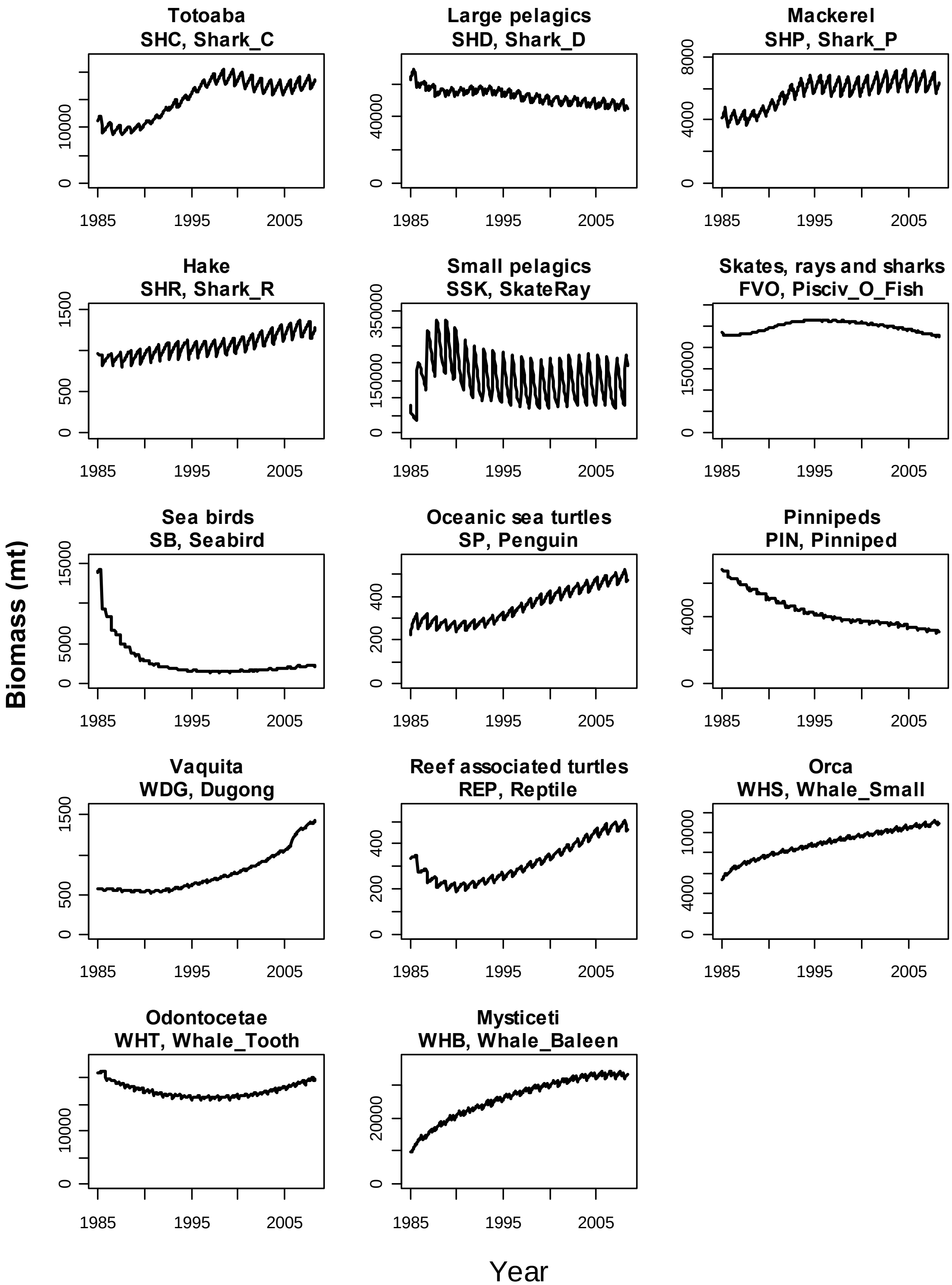


Figure D-4. Biomass dynamics 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for 14 functional groups. Labels show Gulf of California Atlantis model name (e.g., Totoaba), short code (e.g., SHC) and NetCDF code (e.g., Shark_C).

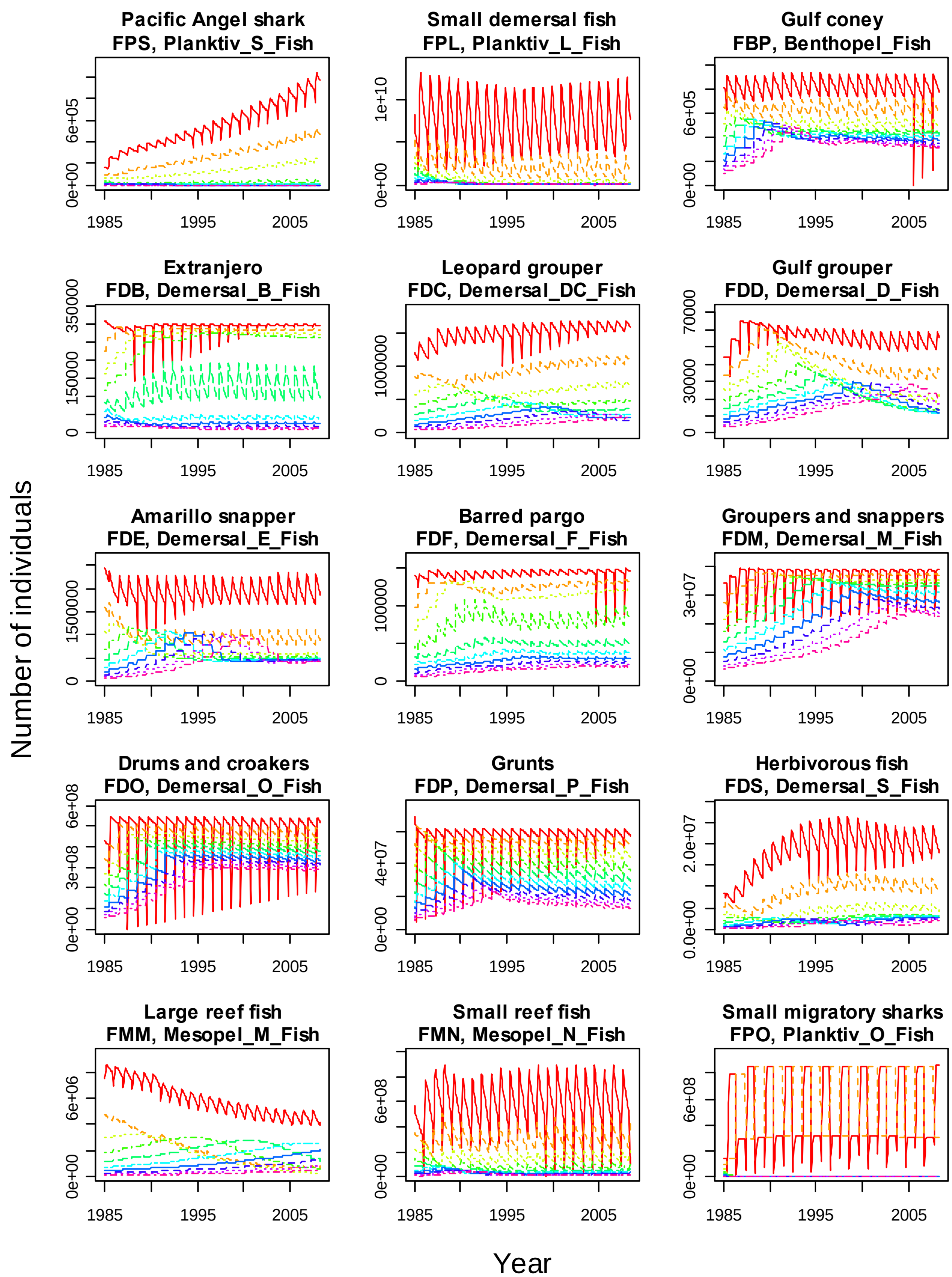


Figure D-5. Numbers dynamics by age-class 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for 15 functional groups. Except for age 0, which is variable, juvenile age-classes are at top and adult age-classes are at bottom. Labels show GOC Atlantis model name (e.g., Pacific angel shark), short code (e.g., FPS) and NetCDF code (e.g., Planktiv_S_Fish).

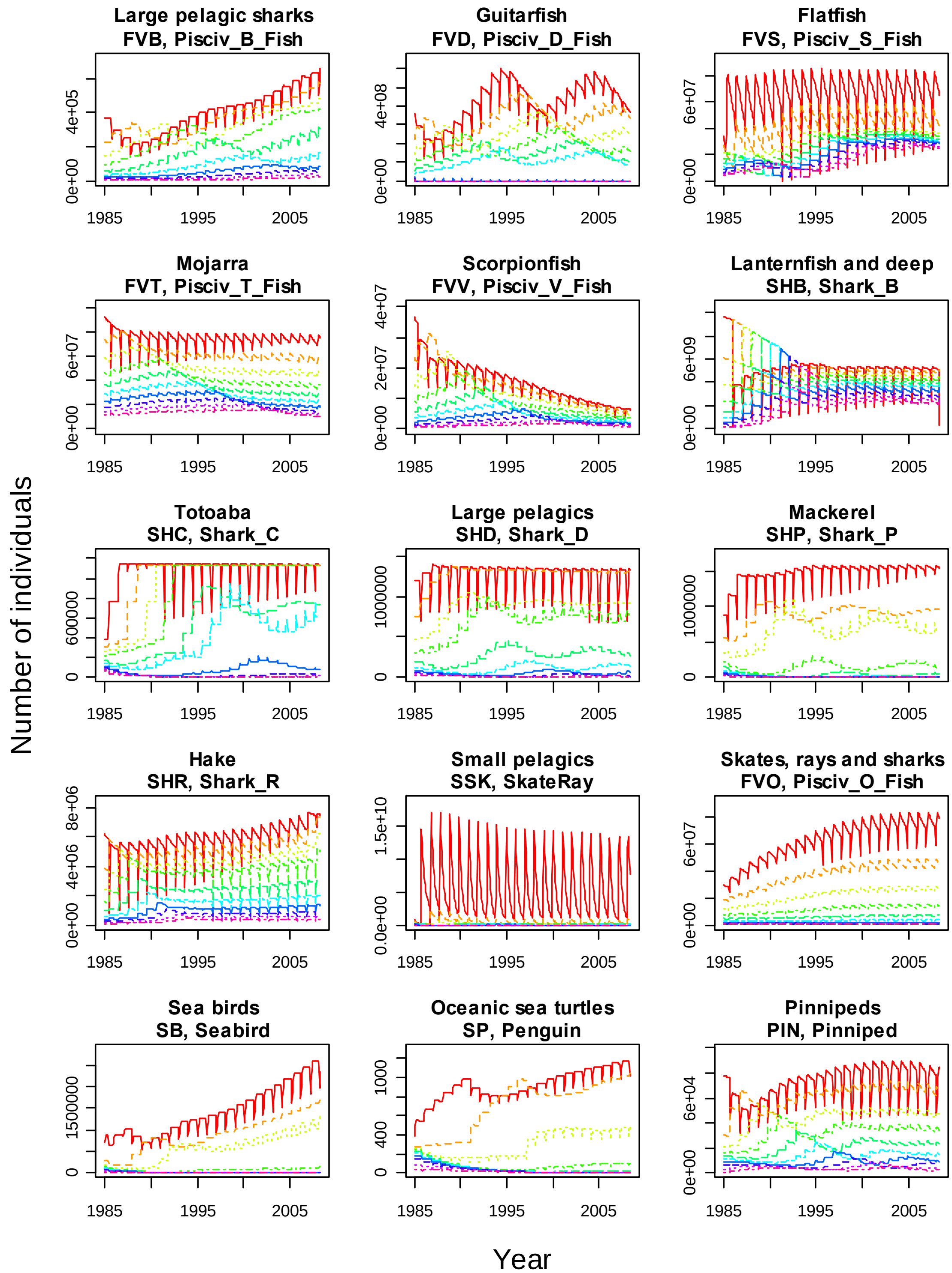


Figure D-6. Numbers dynamics by age-class 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for 15 functional groups. Except for age 0, which is variable, juvenile age-classes are at top and adult age-classes are at bottom. Labels show GOC Atlantis model name (e.g., large pelagic sharks), short code (e.g., FVB) and NetCDF code (e.g., Pisciv_B_Fish).

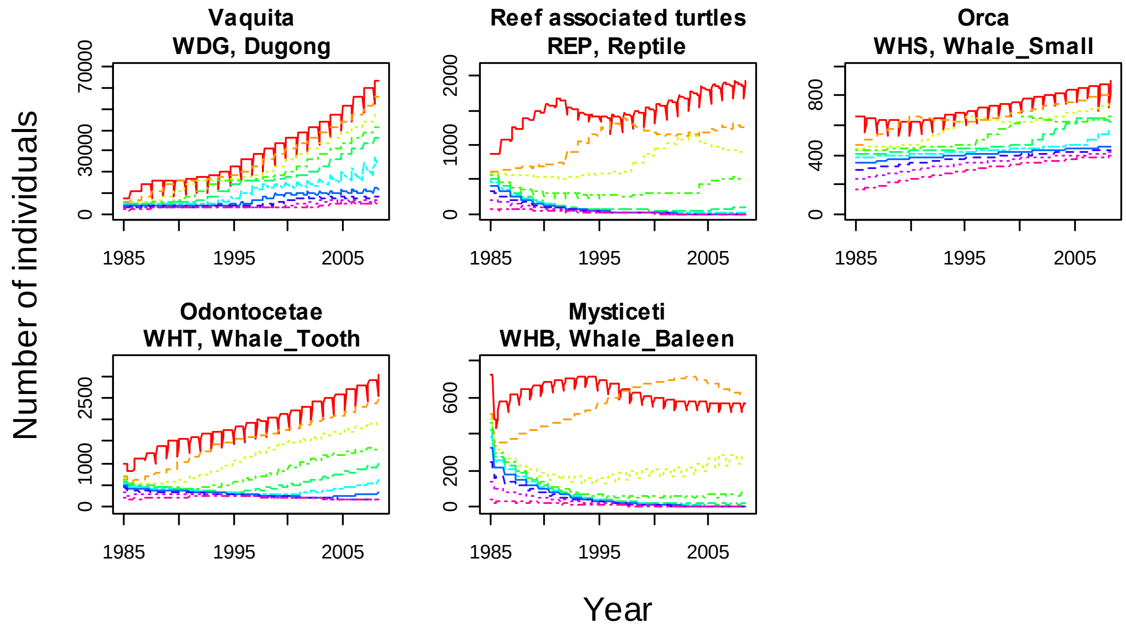


Figure D-7. Numbers dynamics by age-class 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for five functional groups. Except for age 0, which is variable, juvenile age-classes are at top and adult age-classes are at bottom. Labels show GOC Atlantis model name (e.g., vaquita), short code (e.g., WDG) and NetCDF code (e.g., dugong).

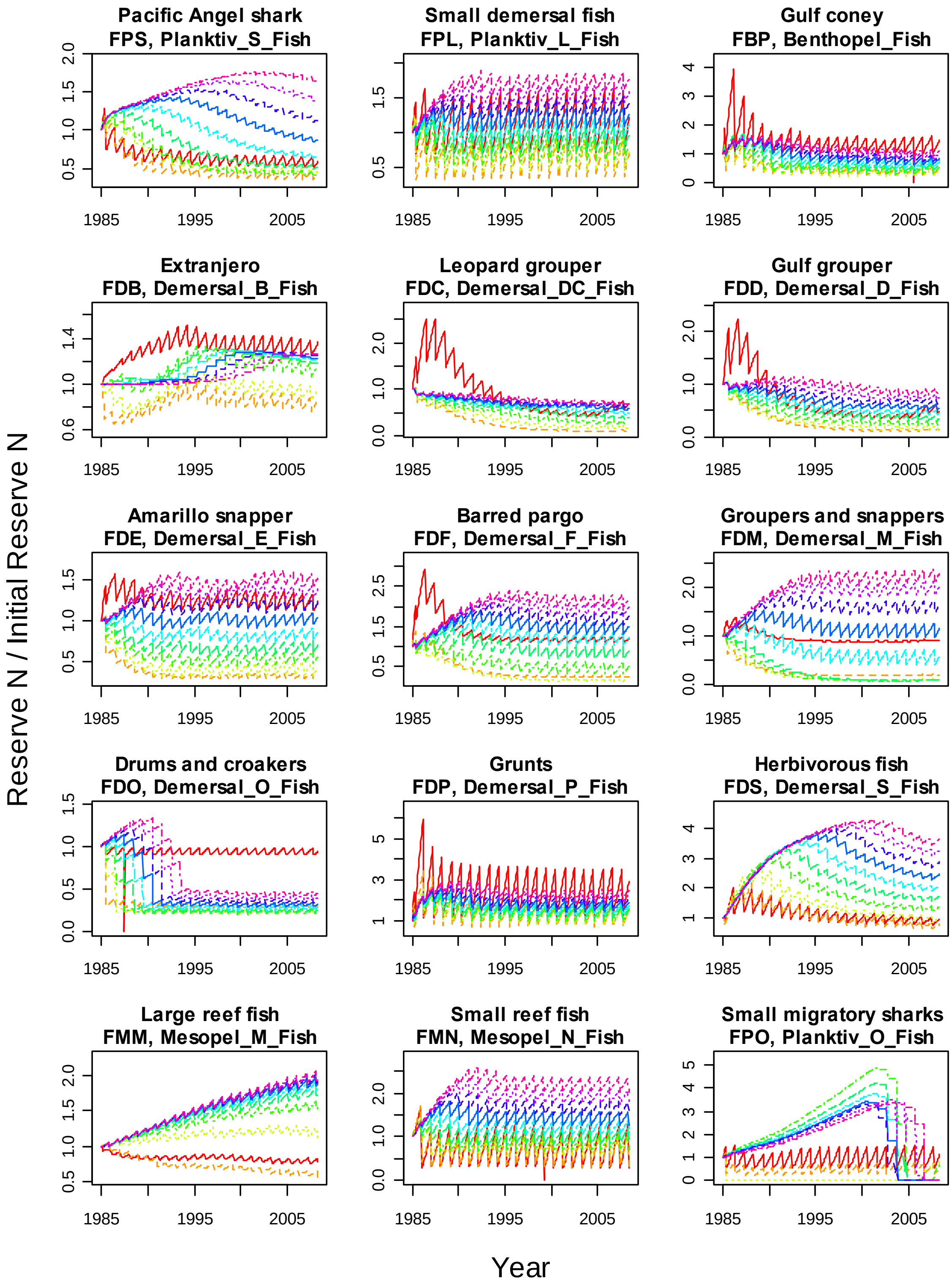


Figure D-8. Reserve nitrogen dynamics by age-class 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for 15 functional groups. Except for age 0, which is variable, adult age-classes are at top and juvenile age-classes are at bottom. Labels show Gulf of California Atlantis model name (e.g., Pacific angel shark), short code (e.g., FPS) and NetCDF code (e.g., Planktiv_S_Fish).

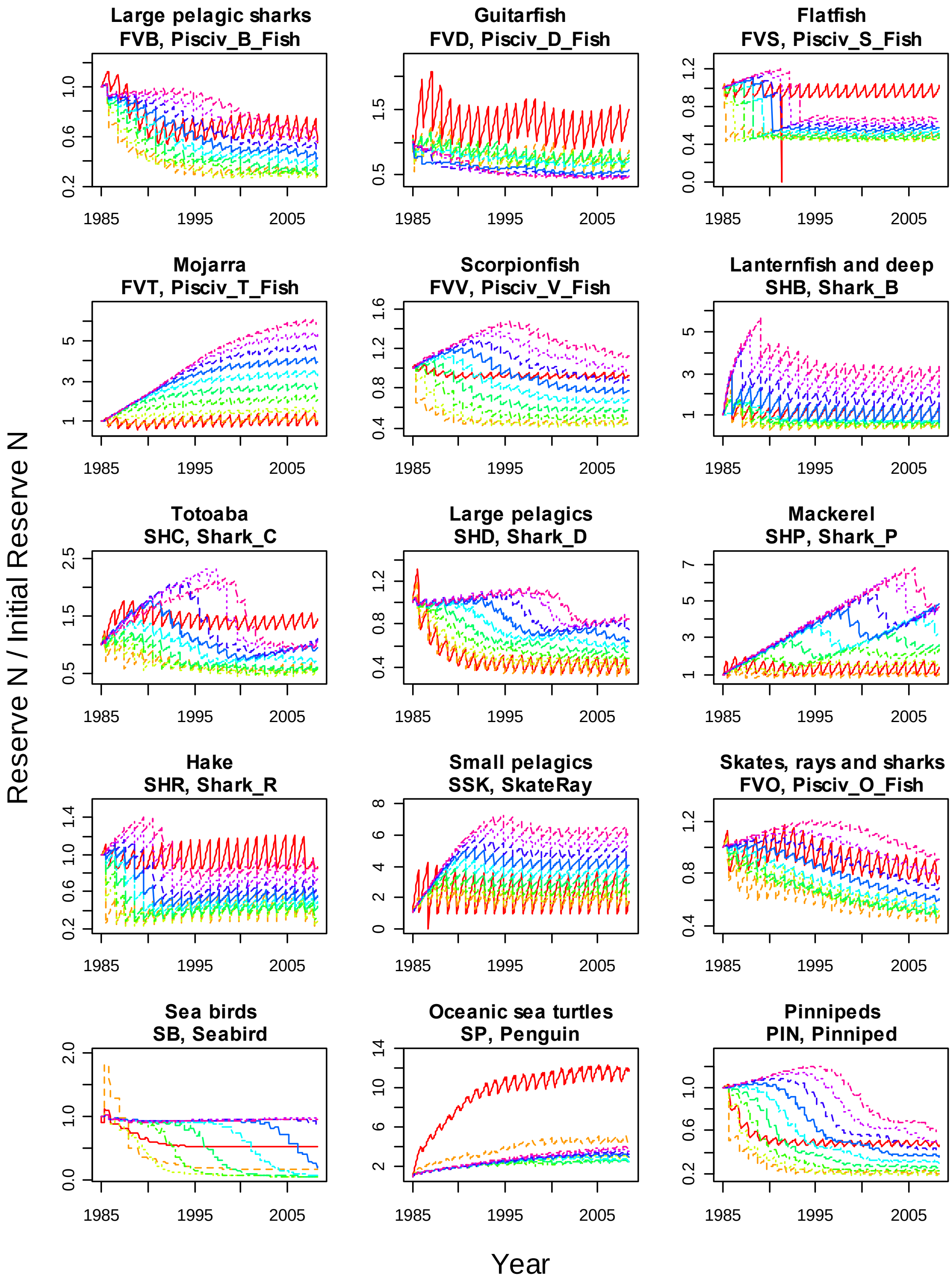


Figure D-9. Reserve nitrogen dynamics by age-class 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for 15 functional groups. Except for age 0, which is variable, adult age-classes are at top and juvenile age-classes are at bottom. Labels show Gulf of California Atlantis model name (e.g., large pelagic sharks), short code (e.g., PVB) and NetCDF code (e.g., Pisciv_B_Fish).

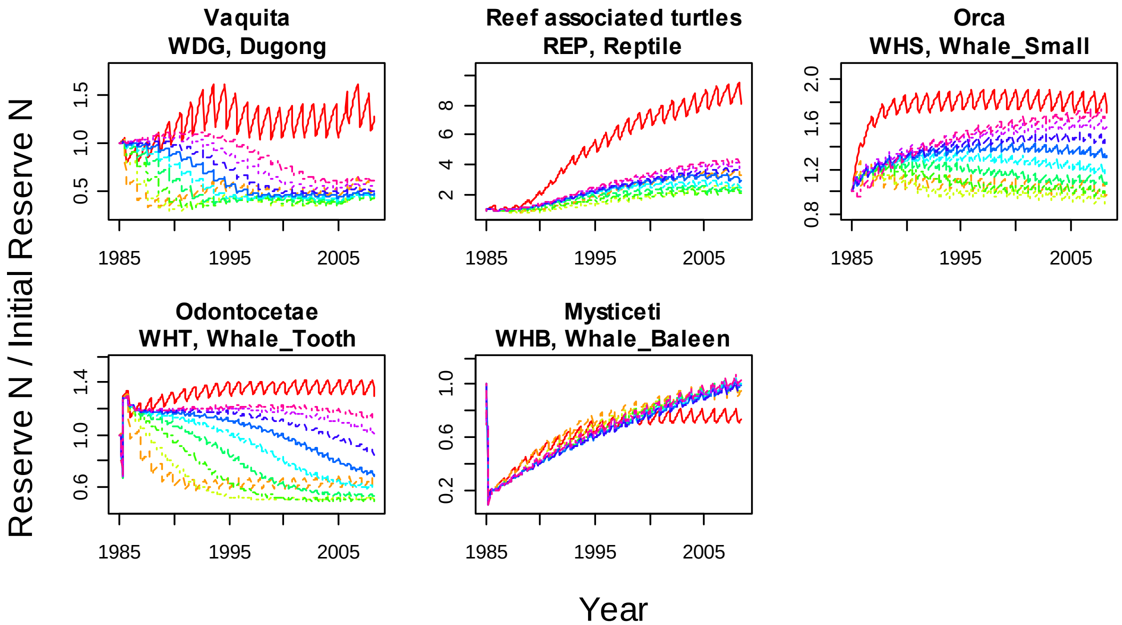


Figure D-10. Reserve nitrogen dynamics by age-class 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for five functional groups. Except for age 0, which is variable, adult age-classes are at top and juvenile age-classes are at bottom. Labels show Gulf of California Atlantis model name (e.g., vaquita), short code (e.g., WDG) and NetCDF code (e.g., dugong).

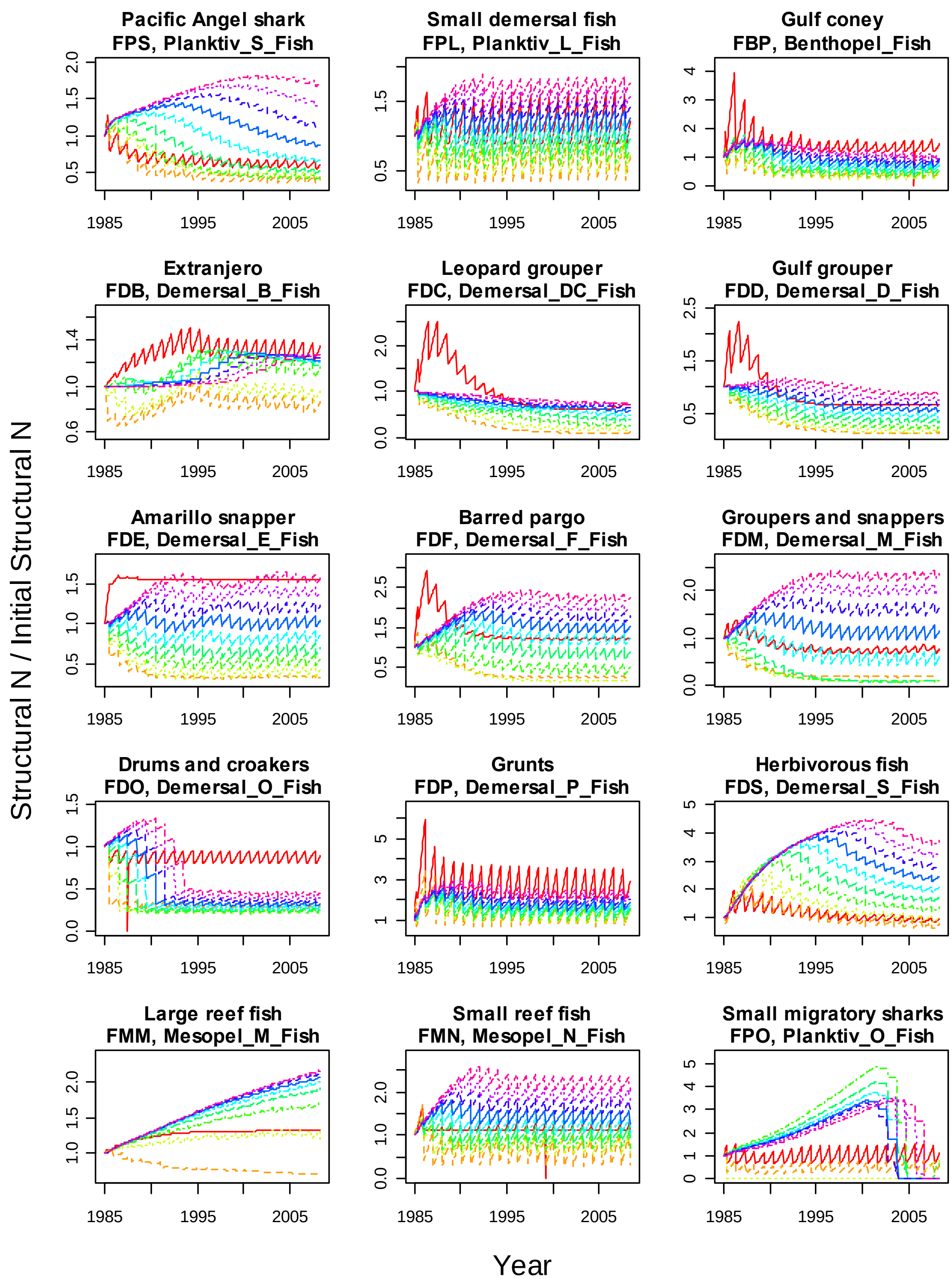


Figure D-11. Structural nitrogen dynamics by age-class 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for 15 functional groups. Except for age 0, which is variable, adult age-classes are at top and juvenile age-classes are at bottom. Labels show Gulf of California Atlantis model name (e.g., Pacific angel shark), short code (e.g., FPS) and NetCDF code (e.g., Planktiv_S_Fish).

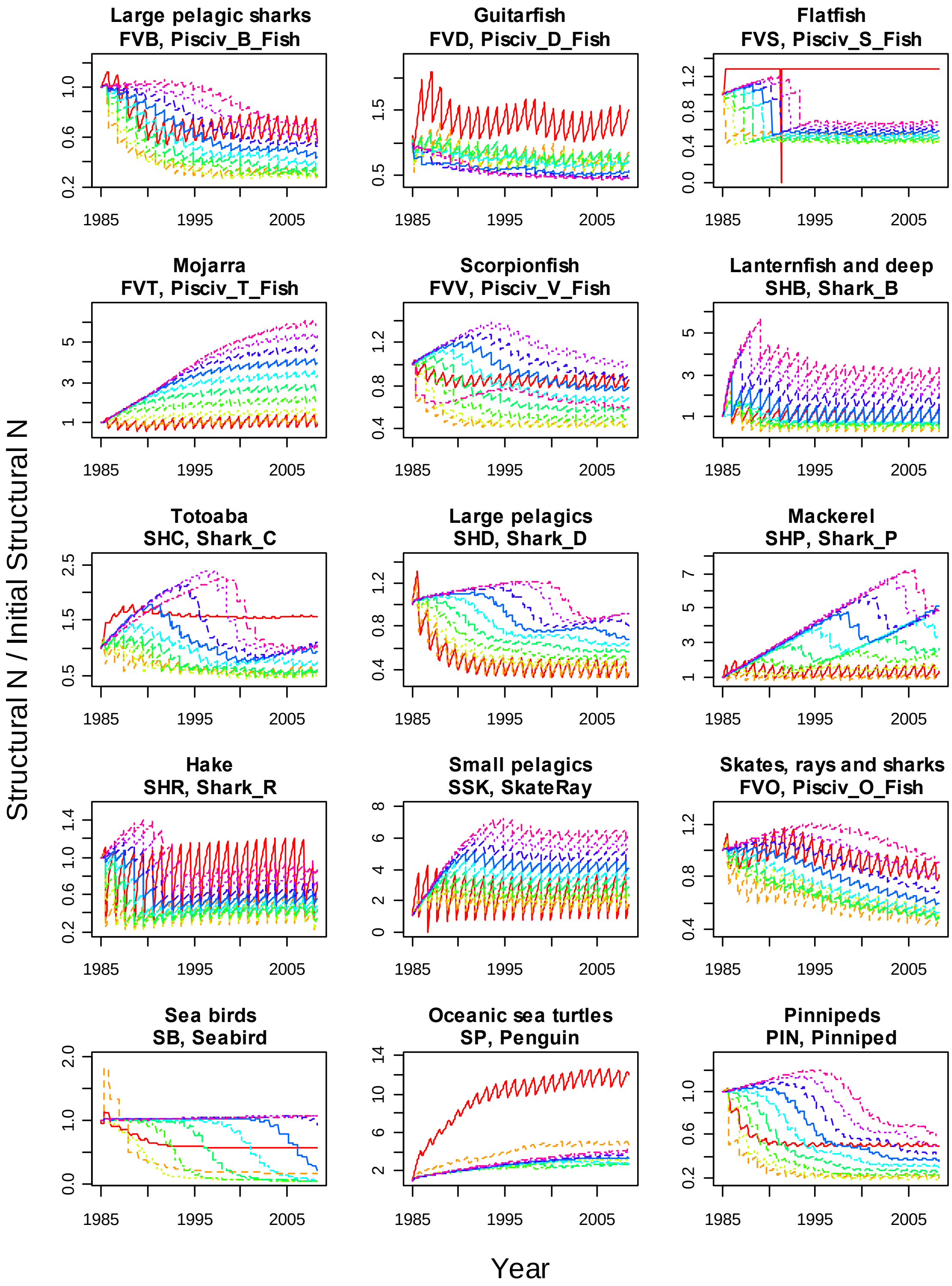


Figure D-12. Structural nitrogen dynamics by age-class 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for 15 functional groups. Except for age 0, which is variable, adult age-classes are at top and juvenile age-classes are at bottom. Labels show Gulf of California Atlantis model name (e.g., Large pelagic sharks), short code (e.g., FVB) and NetCDF code (e.g., Pisciv_B_Fish).

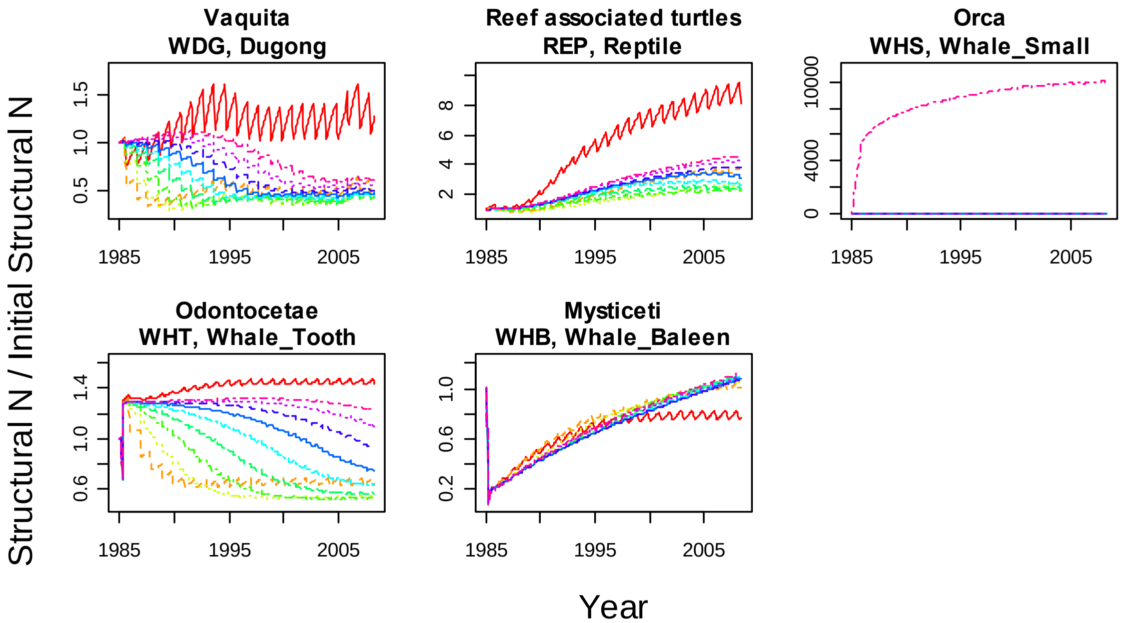


Figure D-13. Structural nitrogen dynamics by age-class 1985–2008 (no fishing scenario, uses historical oceanographic forcing) for five functional groups. Except for age 0, which is variable, adult age-classes are at top and juvenile age-classes are at bottom. Labels show Gulf of California Atlantis model name (e.g., vaquita), short code (e.g., WDG) and NetCDF code (e.g., dugong).

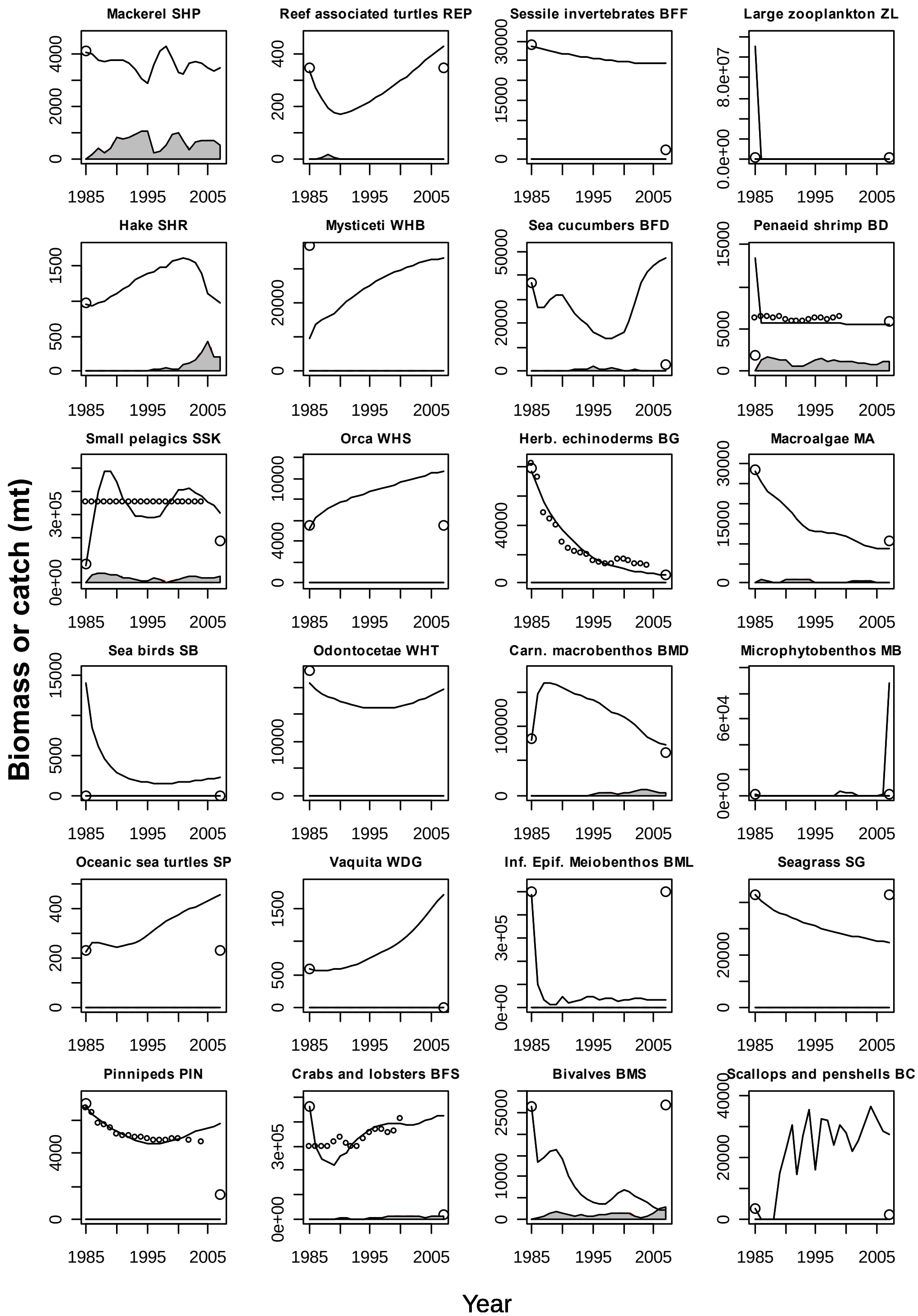


Figure D-14. Annual values of catch and biomass in simulation 1985–2008 (historical reconstruction scenario) for 24 functional groups. Black line shows biomass under historical fishing, shaded area shows catch. Start and end points (large circles) show 1985 and 2008 model biomass values, small circles show available time series data from stock assessment or surveys (residuals are minimized vs. predicted biomass). Historical oceanographic influences from ROMS are in effect.

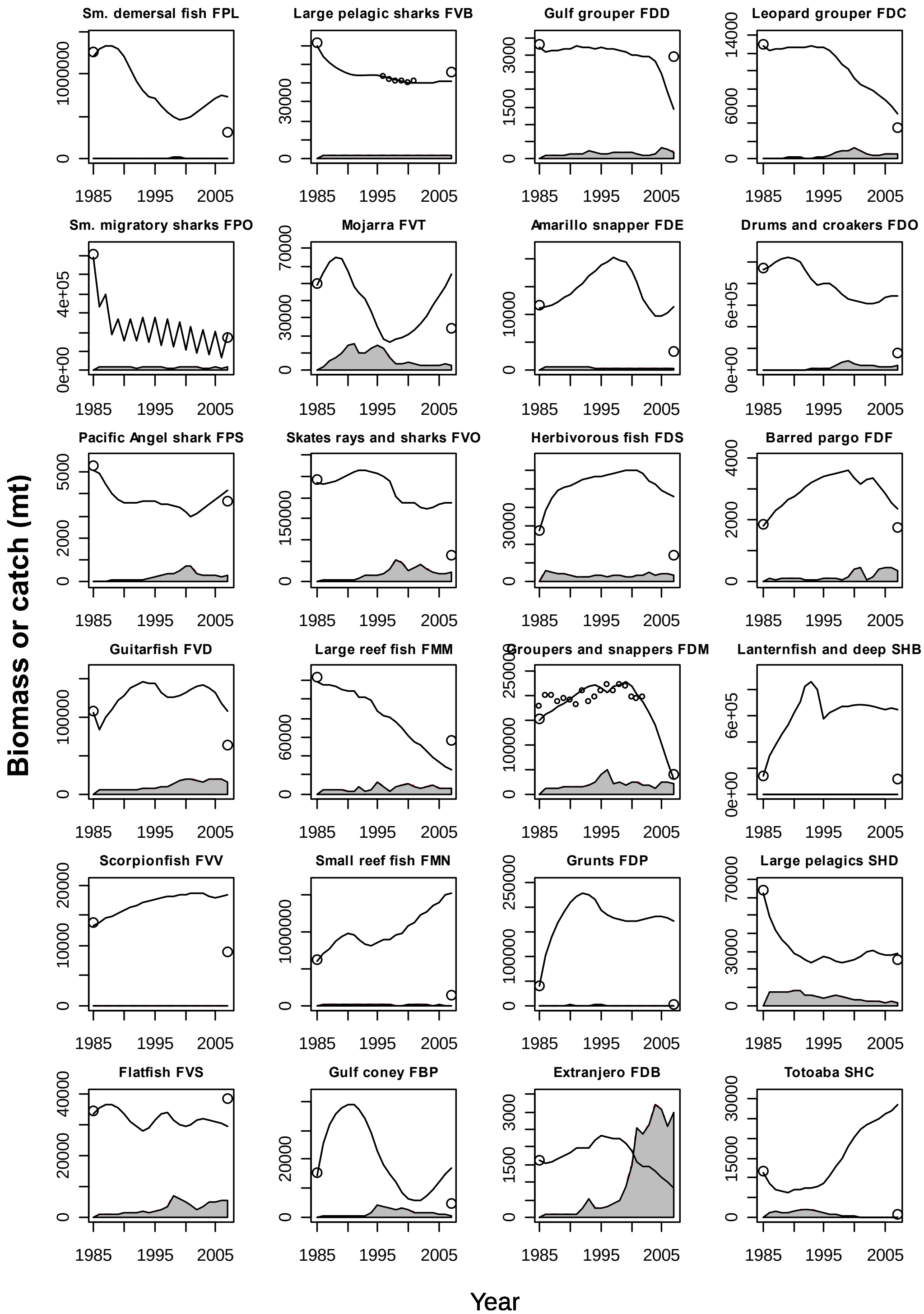


Figure D-15. Annual values of catch and biomass in simulation 1985–2008 (historical reconstruction scenario) for 24 functional groups. Black line shows biomass under historical fishing, shaded area shows catch. Start and end points (large circles) show 1985 and 2008 model biomass values, small circles show available time series data from stock assessment or surveys (residuals are minimized vs. predicted biomass). Historical oceanographic influences from ROMS are in effect.

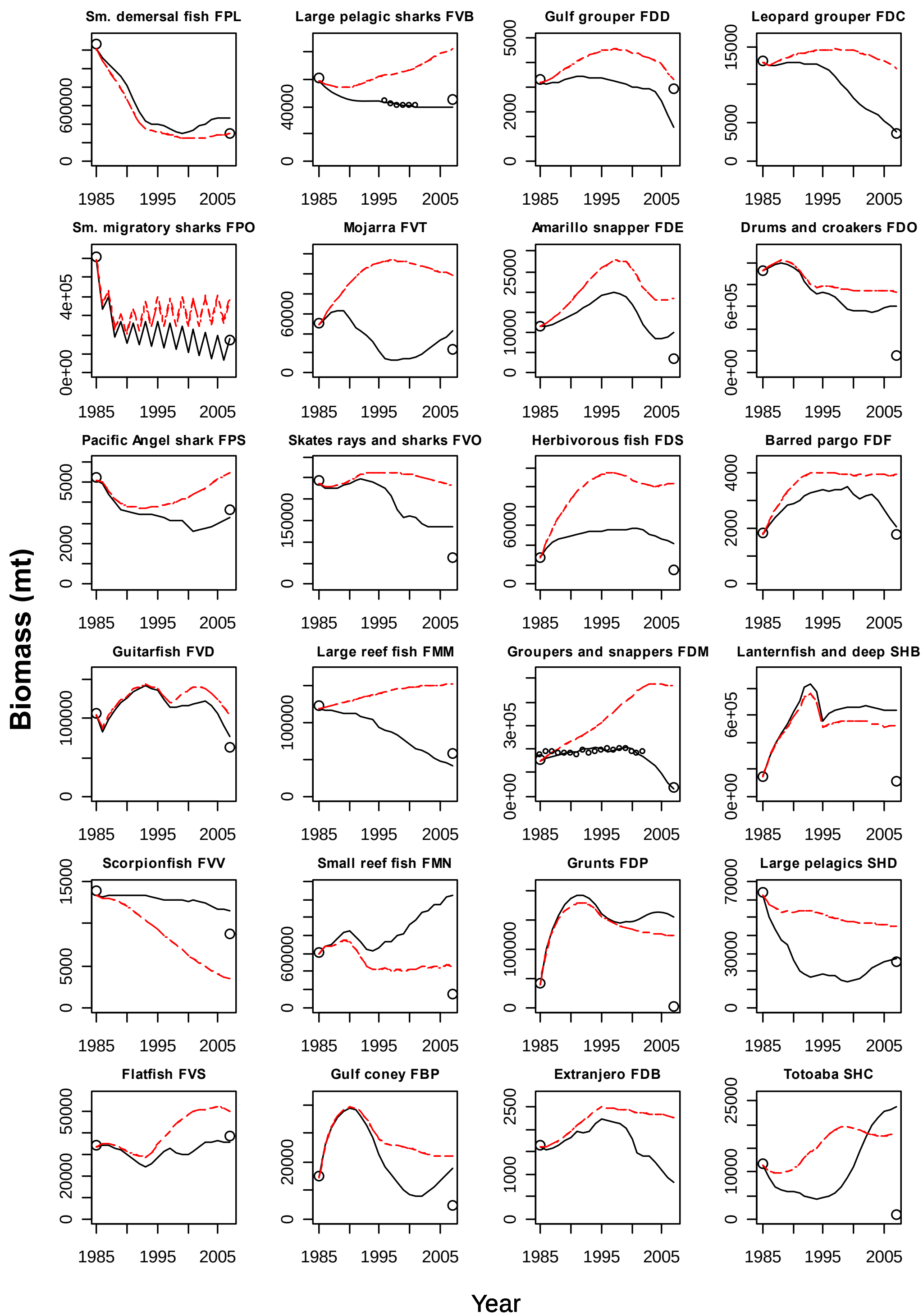


Figure D-16. Annual values of biomass in simulation 1985–2008 for 24 functional groups. Solid line shows historical reconstruction scenario driven by historical catches, dotted line shows biomass under no fishing. Start and end points (large circles) show 1985 and 2008 model biomass values, small circles show available time series data from stock assessment or surveys (residuals are minimized vs. predicted biomass). Historical oceanographic influences from ROMS are in effect.

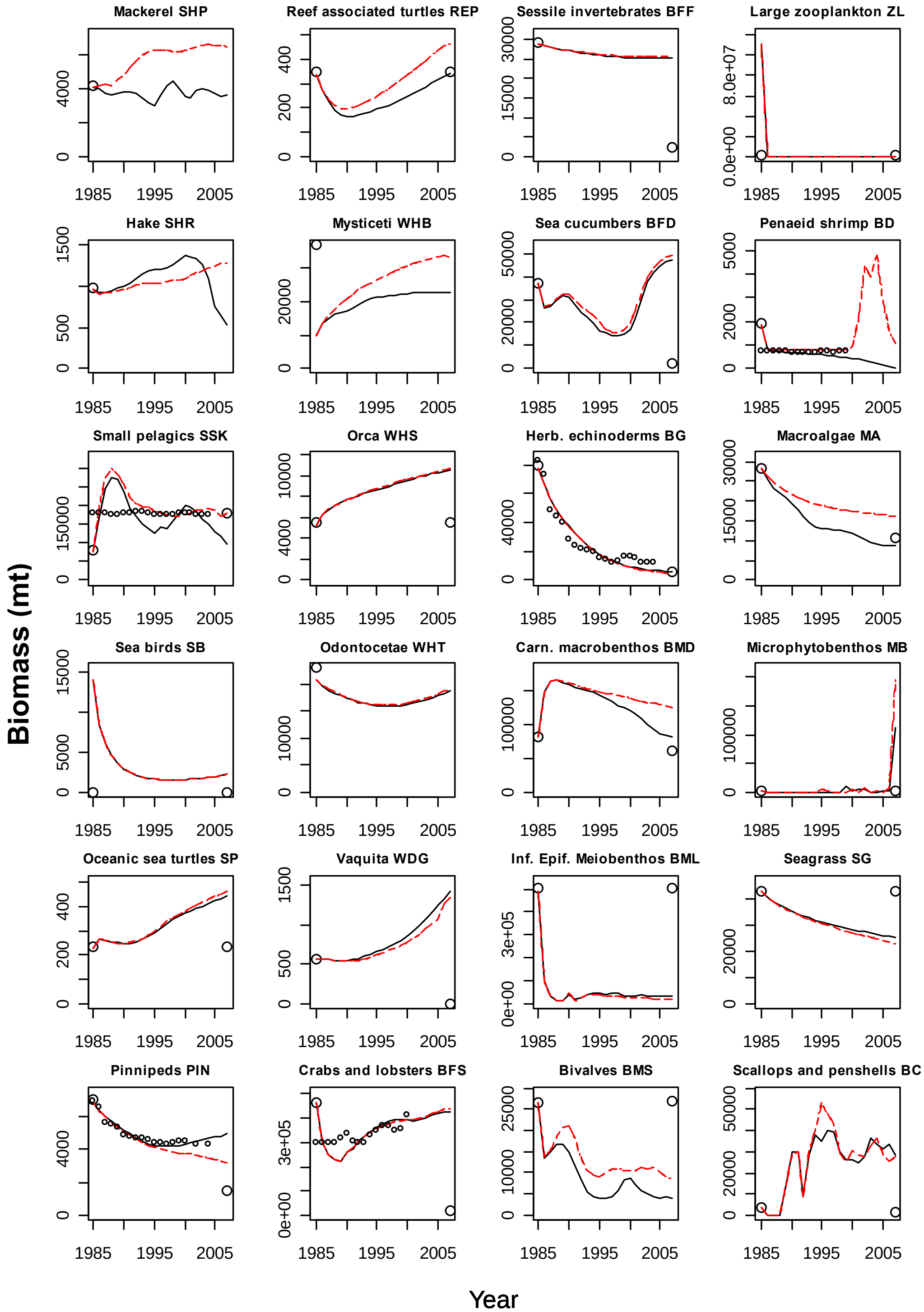


Figure D-17. Annual values of biomass in simulation 1985–2008 for 24 functional groups. Solid line shows historical reconstruction scenario driven by historical catches, dotted line shows biomass under no fishing. Start and end points (large circles) show 1985 and 2008 model biomass values, small circles show available time series data from stock assessment or surveys (residuals are minimized vs. predicted biomass). Historical oceanographic influences from ROMS are in effect.

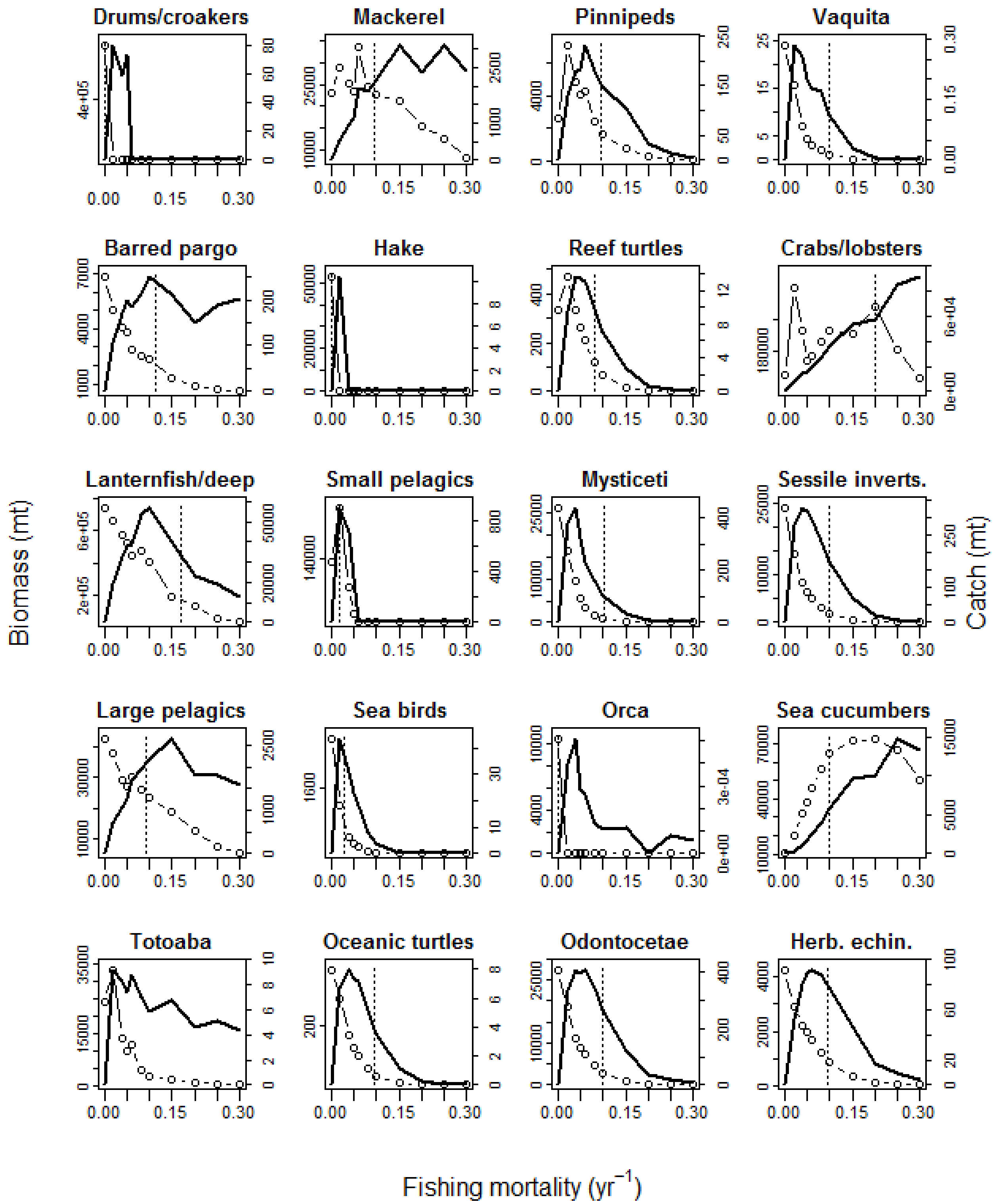


Figure D-18. Multispecies catch and biomass equilibrium plots for 20 functional groups: catch (solid lines), biomass (open circles), and estimated fishing mortality in 2008 (dotted line).

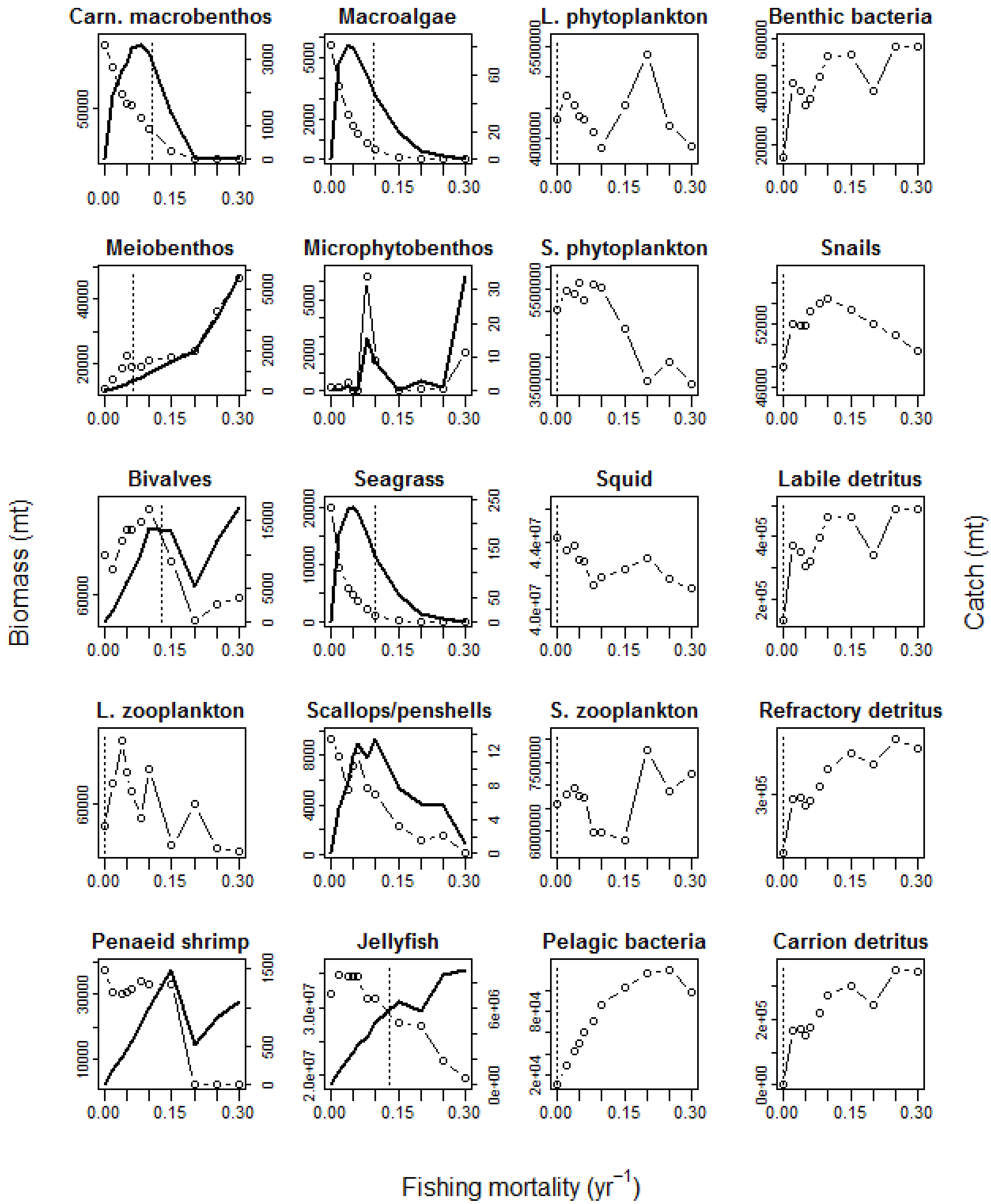


Figure D-19. Multispecies catch and biomass equilibrium plots for 20 functional groups: catch (solid lines), biomass (open circles), and estimated fishing mortality in 2008 (dotted line).

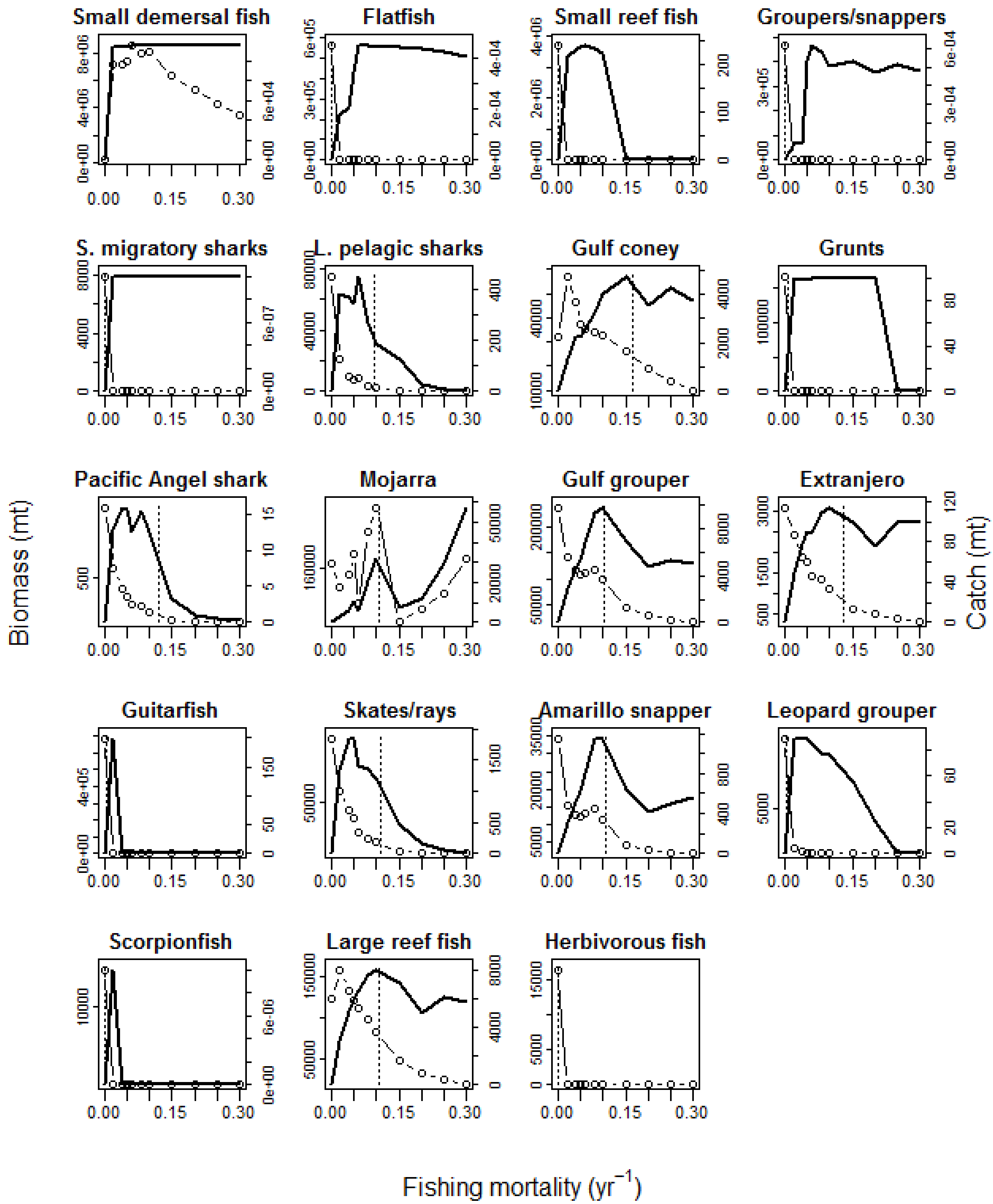


Figure D-20. Multispecies catch and biomass equilibrium plots for 19 functional groups: catch (solid lines), biomass (open circles), and estimated fishing mortality in 2008 (dotted line).

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108 **Drake, J.S., E.A. Berntson, J.M. Cope, R.G. Gustafson, E.E. Holmes, P.S. Levin, N. Tolimieri, R.S. Waples, S.M. Sogard, and G.D. Williams. 2010.** Status review of five rockfish species in Puget Sound, Washington: Bocaccio (*Sebastes paucispinis*), canary rockfish (*S. pinniger*), yelloweye rockfish (*S. ruberrimus*), greenstriped rockfish (*S. elongatus*), and redstripe rockfish (*S. proriger*). U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-108, 234 p. NTIS number PB2011-107576.

107 **Lian, C.E. 2010.** West Coast limited entry groundfish trawl cost earnings survey protocols and results for 2004. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-107, 35 p. NTIS number PB2011-102712.

106 **Harvey, C.J., K.K. Bartz, J. Davies, T.B. Francis, T.P. Good, A.D. Guerry, B. Hanson, K.K. Holsman, J. Miller, M.L. Plummer, J.C.P. Reum, L.D. Rhodes, C.A. Rice, J.F. Samhouri, G.D. Williams, N. Yoder, P.S. Levin, and M.H. Ruckelshaus. 2010.** A mass-balance model for evaluating food web structure and community-scale indicators in the central basin of Puget Sound. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-106, 180 p. NTIS number PB2011-102711.

105 **Gustafson, R.G., M.J. Ford, D. Teel, and J.S. Drake. 2010.** Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-105, 360 p. NTIS number PB2011-102710.

104 **Horne, P.J., I.C. Kaplan, K.N. Marshall, P.S. Levin, C.J. Harvey, A.J. Hermann, and E.A. Fulton. 2010.** Design and parameterization of a spatially explicit ecosystem model of the central California Current. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-104, 140 p. NTIS number PB2010-110533.

103 **Dufault, A.M., K. Marshall, and I.C. Kaplan. 2009.** A synthesis of diets and trophic overlap of marine species in the California Current. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-103, 81 p. NTIS number PB2010-110532.

102 **Reppond, K.D. 2009.** Biochemistry of red king crab (*Paralithodes camtschaticus*) from different locations in Alaskan waters. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-102, 16 p. NTIS number PB2010-110531.

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